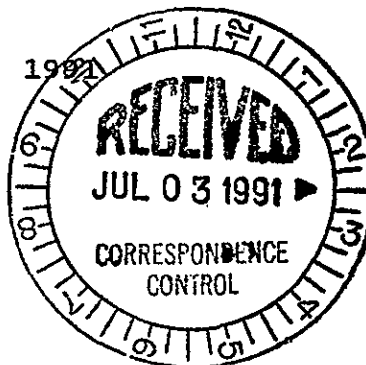




July 1, 1991

Steven H. Wisness
Tri-Party Agreement Manager
U.S. Department of Energy
P.O. Box 550, A5-19
Richland, Washington 99352



Re: Review of the Draft Remedial Investigation/Feasibility Study
Work Plan for the 100-FR-1 Operable Unit, Hanford Site

Dear Mr. Wisness:

In accordance with the Hanford Federal Facility Agreement and Consent Order, the U.S. Environmental Protection Agency (EPA), the Washington State Department of Ecology (Ecology), and their contractors have completed their review of the Work Plan for the 100-FR-1 Operable Unit. The enclosed comments incorporate the reviews of all the parties.

In accordance with the schedule for primary document review specified in the Action Plan, the revised work plan is due to EPA and Ecology within 60 calendar days, i.e., by close of business on August 27, 1991.

Provided for your use is a WordPerfect, Version 5.0, diskette of these comments. If you have any questions, please call me at 376-4919.

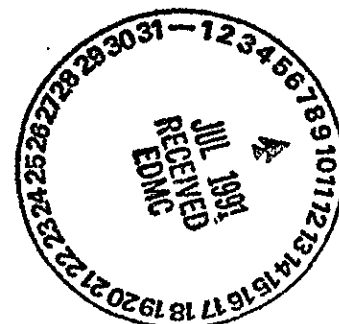
Sincerely,

Pamela S. Innis

Pamela S. Innis
Unit Manager

Enclosures

cc: Larry Goldstein/Richard Hibbard, Ecology
James Goodenough, DOE
George Hofer, EPA
Donna Lacombe, PRC
Linda Powers, WHC
Ward Staubitz/Brian Drost, USGS
John Stewart, USACE
Administrative Record (100-FR-1 Operable Unit)



GENERAL COMMENTS

Before listing all the comments/criticisms of the work plan, the U.S. Environmental Protection Agency (EPA) would like to point out several features of the work plan that we consider to be significant improvements over previous plans:

1. The inclusion of the new work being done on subdividing the Ringold Formation into facies-related units is a definite improvement. This may enable a consistency of unit names across the Hanford Site.
2. Including the dates of known construction changes on the well construction logs allows for a more informed interpretation of the historical water quality and water level data for each well.
3. The work plan contained good coverage of the source units with their relevant histories of use and previous investigations of contamination.
4. The figures showing planned borehole locations at source sites and the configurations of structures, etc., was a good addition to the work plan.

The work plan provides a great deal of information about the operational history, potential contamination, and available analytical data for the operable unit. However, the document is designed for general investigations and is not sufficiently focused on remediation. The data quality objectives do not provide specific data uses. For example, in Table 4-3, for soil, one data use is "define conceptual site model," but the part of the model to be defined based on the soil sampling is not specified. Also, "conduct risk assessment" is mentioned under the data uses column for groundwater only, implying that the soil ingestion and inhalation pathways will not be evaluated.

The text contains discrepancies in the use of existing analytical radionuclide data. Section 3.1.1.1, p. WP3-9 states that "... the quantitative value of the data should be used cautiously." However, Section 3.3.4.2 presents a quantitative risk assessment for the years 1990 and 2090 for ingestion and inhalation of soils at seven contaminant sources, and for groundwater ingestion sitewide. This use of the data appears inconsistent with the earlier statement on the usability of existing data.

The preliminary risk assessment section (Section 3.3) presents information on contaminants of concern and preliminary risk evaluations in a manner that might be misleading. The reader could conclude that the risk estimates given in this section are final estimates. For example, on p. WP3-134 the text states, "A risk characterization for humans has been carried out on the potential exposure from drinking water ingestion of radionuclides and chemicals found in monitoring wells." The word "preliminary" should be inserted in front of "risk characterization" to clarify its preliminary

status. Other examples include Tables 3-36 and 3-37, which present lifetime carcinogenic and noncarcinogenic risks, respectively, from groundwater ingestion. Again, the word "preliminary" should appear in the table titles. In general, Section 3.3 should be examined and the word "preliminary" inserted where appropriate.

Additionally, the preliminary risk assessment section ignores the U.S. Environmental Protection Agency (EPA) Region 10 risk assessment guidance (EPA 1990a) that was current when the work plan was prepared. For example, Table 3-30 presents exposure assumptions used in the preliminary risk assessment, giving 70 years as the parameter for both the number of years exposed and the averaging time. However, Region 10 guidance specifies 75 years. The Region 10 guidance should be reviewed and the appropriate parameters should be used in Section 3.3. This section should also present a discussion regarding the uncertainties inherent in the preliminary risk estimates. This discussion should address the concerns presented in Section 8.4 of the Superfund risk assessment guidance (EPA 1989). Finally, Region 10 guidance has been superseded by OSWER Directive No. 9285.6-03, dated March 25, 1991 (Attached). This directive is entitled "Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors." While it is acceptable to use EPA 1989 and EPA 1990a references for the preliminary risk assessment, the remedial investigation baseline risk assessment should be performed using the new OSWER directive.

The baseline risk assessment section (Section 5.1.12) discusses the steps involved in the determination of potential health and environmental risks. In general, the approach is acceptable, with the exception of the use of applicable or relevant and appropriate requirements (ARARs) as acceptable levels for human exposure. It is not correct to use ARARs as acceptable levels in the human baseline risk assessment because ARARs are not consistent with respect to risk. For example, the level of risk used for developing an ARAR for one contaminant may be 10^{-2} , while for another contaminant the risk level used may be 10^{-5} . Baseline risk assessments focus on a 10^{-6} risk level for carcinogens. Also, Group C carcinogens are not treated as carcinogens during ARAR development. However, slope factors for Group C carcinogens should be included in the baseline risk assessment. ARARs should be used in the ecological portion of the baseline risk assessment, and ARARs are necessary tools for feasibility study decisions.

There are inconsistencies in organization and presentation of the information for source units throughout the work plan and the field sampling plan. No rationale is provided for sampling locations, sampling intervals, sampling depths, or analytical parameters for source and vadose zone characterization, either in the work plan or in the field sampling plan. There is no explanation for the omission of surface or near-surface soil sample collection from most of the sources.

EPA (1990b) recommends that background samples be collected and analyzed prior to the final determination of the sampling design, since the number of samples is significantly reduced if little background contamination is present. Hence, a timeframe should be specified to establish the site-specific background sample locations for surface and subsurface soil

characterization, to allow time for review of the sampling approach and the adequacy of the samples.

The quality assurance project plan (QAPP) addresses the 16 items required in a QAPP (EPA 1983a). However, the following critical information is omitted:

- The precision, accuracy, representativeness, comparability, and completeness parameters are not addressed for all parameters or sample types.
- The methods proposed are inadequately or inappropriately referenced.
- Several parameter groups do not have methods referenced or provided for review.
- Inappropriate methods are proposed for soil analyses.
- None of the precision, accuracy, or completeness goals are presented for soil analyses.
- Ecological parameters and methods are not identified.
- The QAPP text does not clearly identify the analytical data to be validated or the validation criteria.

The health and safety plan presents thorough procedures for ensuring health and safety while performing field activities at the operable unit. The plan meets the requirements specified in the Occupational Safety and Health Administration regulation on hazardous waste operations and emergency response (29 CFR 1910.120). However, Washington state regulations on health and safety should also be included in the plan. In addition, inclusion of examples of a hazardous waste operating permit and a radiation work permit would provide an additional level of detail not given in the generic plan.

SPECIFIC COMMENTS

WORK PLAN

1. Comment: Section 1.0, p. WP1-1, third paragraph

The 100-FR-1 Operable Unit is considered a source and groundwater unit.

2. Comment: Section 1.1, p. WP1-4, third paragraph

See comment 1.

3. Deficiency: Section 1.1, p. WP1-5, first paragraph

This paragraph states, "The RI/FS does not include evaluating the general impacts of previous reactor operations . . . handled by the Defense Decontamination and Decommissioning Program," but specific reasons for omitting the evaluation of impacts are not stated.

Recommendation:

The general impacts from previous reactor operations should be identified and evaluated to determine whether those impacts had an effect on the operable unit.

4. Deficiency: Section 1.1, p. WP1-5, second paragraph

In the last sentence, the statement ". . . existing data that may not be complete or validated" is vague and uninformative.

Recommendation:

A clear statement on the quality of existing data should be included. A thorough evaluation of existing data is needed to help prevent duplication of previous efforts and to facilitate a remedial investigation that is more focused and therefore more efficient in its expenditure of resources.

5. Deficiency: Section 1.2, p. WP1-5, second paragraph

Recommendation for an early action if an imminent threat exists is not included as one of the data-gathering objectives of the remedial investigation.

Recommendation:

The objective, "Recommend an early removal action such as classic emergencies, time-critical removal actions, and non-time critical removal actions based on the urgency of any imminent threats" should be included in the data-gathering objectives of the remedial investigation (EPA 1987a).

6. **Deficiency:** Section 2.1.6.1.2, p. WP2-15

A sizeable amount (approximately 10 percent) of the process tubes were held in the fuel storage basin for the decay of short-lived radionuclides. This operation occurred about once a month, generating contaminated water within the basin. Information on the disposal of contaminated water during normal operation other than fuel element rupture within the basin is not mentioned.

Recommendation:

The information on the frequency with which the fuel storage basin was drained during normal operations, the disposal location for the contaminated water, and the concentrations of radionuclides in the storage basin water should be described to help determine whether the fuel storage basin area is a potential source of contamination.

7. **Deficiency:** Section 2.1.6.1.3, p. WP2-15

This section addresses decontamination activities during reactor operations and reactor shutdowns. Information is not provided on the quantities of decontamination solutions generated, the frequency of generation, the method of disposal (such as trenches or pits in the immediate vicinity of the building where they were used), and where the solutions were combined with cooling water before discharge to the river.

Recommendation:

Detailed information on decontamination procedures should be included to help determine the sources and the extent of contamination associated with decontamination activities.

8. **Deficiency/Recommendation:** Section 2.1.6.2.2, p. WP2-16

The following information on the disposal areas and the nature of discarded reactor components should be included:

- Facility identification numbers for disposal of highly contaminated irradiated reactor components
- The type of miscellaneous irradiated radioactive components and other irradiated hardware

9. **Deficiency/Recommendation:** Section 2.1.6.2.4, p. WP2-17

The information given in this section for the radioactive solid waste generated from decommissioning operations is not adequate. The following information should be included: the amount of wastes generated; the disposal facility identification number (if used in the

F-area); the amount of wastes remaining at the facility locations in the form of demolition debris, foundation structures, buried concrete-lined tunnels, and buried pipelines; and the type of surface treatment chemicals used to treat the residual contamination.

The 116-F-14 retention basin is included in the demolished facilities in the operable unit. In Section 2.1.6.2.1, the text states that approximately 200 tons of sludge remains in the 116-F-14 retention basin. It is unclear whether the 116-F-14 retention basin is existing or demolished; its status should be described clearly.

10. **Deficiency/Recommendation:** Section 2.1.6.4, p. WP2-18

Information should be provided on the amount of ash generated from the incineration of contaminated animal carcasses, including ²³⁹Pu-contaminated carcasses and animal wastes from the dog experiments.

11. **Deficiency:** Section 2.1.6.5, p. WP2-18

Facility identification numbers are not indicated for the five septic tank and leach field waste disposal locations for the sanitary wastes; other wastes containing detergents, cleaning compounds, and solvents; and laboratory wastes containing radioactive and hazardous chemical contaminants.

Recommendation:

The current status and the facility identification numbers for the five septic tanks and leach fields should be included to help evaluate the locations of these facilities as possible sources of contamination.

12. **Deficiency:** Section 2.1.6.6, p. WP2-19

Information on the following components of nonradioactive liquid waste generation and disposal processes is not provided in this section:

- Water treatment sludges from settling tanks
- Filter backwash water
- Wastewater generated from cleaning of mixing chambers, flocculators, and valve pits
- Water treatment sludge from boiler water treatment units

Recommendation:

Additional information on the amount of liquid wastes generated and methods of disposal of these wastes should be included to help determine the potential contaminant sources during the investigation.

13. **Deficiency/Recommendation:** Section 2.1.6.7, p. WP2-19, second paragraph

The disposal facility for other solid waste consisting of uncontaminated concrete, metal parts, asbestos, chemical waste, and contaminated solids is not identified. The facility identification number should be included to help locate the disposal area within the operable unit.

14. **Comment:** Section 2.2.3.3, p. WP2-29

It is stated that the Plio-Pleistocene, "Palouse", and pre-Missoula comprise the sequence above the Hanford Formation. This should read, "above the Ringold Fm. and below the Hanford Fm".

15. **Comment:** Section 2.2.3.3.3, WP2-31, first sentence

The Hanford Formation rests unconformably, not uncomfortably upon the Ringold Formation.

16. **Comment:** Table 2-2, p. WP2-33

The table indicates monitoring intervals of 22-45 and 65-90 for well 199-F5-3, but figure 2-12 shows a plug at 63 ft.

17. **Comment:** Table 2-2, p. WP2-33

The table indicates a monitoring interval of 16-82 feet for well 199-F8-2, but a drill depth of only 55 feet.

18. **Comment:** Figure 2-14, p. WP2-41

The figure should show the casing continuing to 150 feet with cement filled to 82 feet.

19. **Comment:** Figure 2-15, p. WP2-42

The figure implies a stickup of the surface casing of 9.74 feet (LSL=380, top of casing 389.74 feet). Elevation values should be checked.

20. **Comment:** Figure 2-16, p. WP2-43

The well installation date is 8/1960, rather than 8/1980.

21. **Comment:** Figure 2-19, p. WP2-46 and Figure 2-7, p. WP2-34

The spacing of wells in the cross-section does not match the spacing shown on the map.

22. **Comment:** Figure 2-20, p. WP2-47

The spacing of wells 199-F8-1, 199-F8-2, and 199-F5-4 in the cross-section does not match the spacing on the map.

23. Comment: Figure 2-20, p. WP2-47

On the southwest end of the cross-section (at 699-77-36 and 199-F7-1), no contact is drawn between the Hanford and FSC.

24. Comment: Figure 2-22, p. WP2-50 and Figure 2-20, p. WP2-47

The isopach map indicates no Hanford at 699-77-36, but the cross-section shows Hanford above the FSC (with no contact drawn).

25. Deficiency: Figure 2-22, p. WP2-50, Figure 2-24, p. WP2-52

These figures do not include units on the data that is shown.

Recommendation:

Revise the figures to include units.

26. Comment: Figure 2-22, p. WP2-50

Are the data sufficient to draw contours as shown (with closure to northwest and southeast)? Are there data to northwest and southeast indicating Hanford thicknesses of less than 10 feet?

27. Comment: Figure 2-23, p. WP2-51

The explanation indicates that the number in parentheses at each well is the elevation of the top of the casing. Apparently the number is actually the elevation of the top of the Ringold.

28. Comment: Figure 2-23, p. WP2-51

Are data sufficient to draw contours as shown (with closure to the northwest and southeast)? Are there data to the northwest and southeast indicating Ringold elevations of less than 370 feet and less than 380 feet, respectively?

29. Deficiency: Figure 2-23, p. WP2-51, Figure 2-25, p. WP2-53

These figures should reference the elevation in feet above sea level.

Recommendation:

Revise these figures.

30. Comment: Figure 2-24, p. WP2-52

See comment on figure 2-23 regarding contour closures.

31. **Comment:** Figure 2-25, p. WP2-53

See comment on figure 2-23 regarding explanation.

32. **Deficiency:** Figure 2-26 and 2-27, pp. WP2-55 and WP2-56

The units of measurement for these figures are different. This work plan should be consistent by listing all units in feet, meters, or both.

Recommendation:

Revise the unit on the above mentioned figures to be consistent.

33. **Comment:** Figure 2-29, p. WP2-59

The 375 contour includes an erroneous number of 100.

34. **Comment:** Section 2.2.6.2.4, p. WP2-61

We do not understand the sentence, "Artificial recharge encroachment of the vadose zone creating groundwater mounding in the 100-N Area has reduced the effective vertical thickness of the Hanford Aquifer."

35. **Comment:** Section 2.2.7.4, p. WP2-65

It is stated that a landslide across the river in the White Bluffs could block the Columbia River and lead to inundation of the 100-F Area (DOE, 1987). You may also want to reference Schuster, Chleborad, and Hays (The White Bluffs landslides, south-central Washington: in Engineering Geology in Washington, Volume II, Washington Division of Geology and Earth Resources, Bulletin 78, pp. 911-926, 1987) who studied the White Bluffs and concluded that "...fear of such a catastrophe is not realistic."

36. **Deficiency:** Section 2.2.9.4, p. WP2-72

This section is lacking a discussion of the residential scenario. Future land uses of this property could include people living on or adjacent to this site. WAC 173-740-745 states that:

- (b) Cleanup levels shall not be based on industrial site use unless the following can be demonstrated.
 - (ii) The site is currently used for industrial purposes or has a history of use for industrial purposes.
 - (iii) Adjacent properties are currently used or designated for use for industrial purposes.
 - (iv) The site is expected to be used for industrial purposes for the foreseeable future due to site zoning, statutory or

regulatory restrictions, comprehensive plans, adjacent land use, and other relevant factors.

The person undertaking the cleanup action must demonstrate that it is appropriate to use other than residential levels.

Recommendation:

Revise the text to discuss the potential future land use associated with a residential scenario.

37. Comment: Section 2.2.9.5.1, p. WP2-76

This section should mention the City of Richland well field and its location.

38. Deficiency: Section 3.1.1.1, p. WP3-9

It is noted that sludge was removed from the 116-F-14 retention basin at least once during reactor operation and that there is no record of where the sludge was disposed. The existing sludge in 116-F-14 contained 93 curies of radiation when measured in 1975-76 and that equalled about 72 percent of the total radiation found in the 100-FR-1 Operable Unit. It is likely that the sludge previously removed from the 116-F-14 retention basin was also highly radioactive and constitutes a significant waste unit. However, we see no task in the work plan directed towards identifying the location and characterizing the nature of the sludge.

Recommendation:

At other 100 Area reactor sites, sludge from retention basins was often disposed of in trenches located near the retention basins. We recommend investigating sludge disposal practices at other 100 Area reactor sites, contacting former 100 Area personnel for anecdotal information, and conducting surface geophysical surveys in the vicinity of the 116-F-14 retention basin to identify any possible undocumented waste-disposal trenches. If the disposal trenches are identified, sampling should be conducted.

This investigation should be noted as a 100-FR-1 study task, and the location and nature of 116-F-14 sludges should be noted in the work plan as a significant existing data gap.

39. Comment: Section 3.1.1.1.1., p. WP3-11, Figure 3-2, p. WP3-12, and Table 3-4, p. WP3-13

Was station "S" near 128-F-2 a "background" station? In table 3-4, "S" is listed with the "Basin Sludge" and "Below Basin Floor" groups.

40. **Comment:** Figure 3-2, p. WP3-12

The locations of the sample holes depicted in this figure do not correspond with those in Figure 2.7-8 of Dorian and Richards. Clarify the discrepancy

41. **Comment:** Figure 3-2, p. WP3-12 and Table 3-4, p. WP3-13

The backhoe sample locations listed in the table (AN, DS, AS, BN, CN, and CS) cannot be found in the figure.

42. **Comment:** Table 3-4, WP3-13, Table 3-5, p. WP3-14, Table 3-6, p. WP3-18, Table 3-7, p. WP3-22, and Table 3-10, p. WP3-36 and 37

What does the dot stand for? Non-detects?

43. **Deficiency/Recommendation:** Section 3.1.1.1.4, p. WP3-19, first paragraph

The last sentence states, "Portions of the steel pipes have been removed and stored in the retention basin for later decommissioning activities." The retention basin no longer exists (Section 3.1.1.1.1). Portions of the steel pipes are buried at the retention basin site and covered with backfill material. Hence, the statement is inaccurate and should be revised. The portions of the steel pipes that were removed should be shown in Figure 3-4.

44. **Deficiency/Recommendation:** Figure 3-4, p. WP3-20

In Section 3.1.1.1.4, Figure 3-4 is referenced for four sample borings along the above-ground sections of the 42-inch and 60-inch pipes. The figure does not clearly distinguish the 42-inch pipe from the 60-inch pipe. The 42-inch and 60-inch pipes should be clearly marked for identification.

45. **Deficiency/Recommendation:** Section 3.1.1.1.5, p. WP3-21

The text in this section is confusing. Figure 3-4 is referenced for other potential contaminant source areas such as EM bypass ditch, the basin leak ditch, and effluent springs along the Columbia River bank. However, Figure 3-4 does not indicate these other sources. The other sources should be clearly marked in Figure 3-4 to identify them. The sample location points associated with these sources should also be clearly indicated on the figure.

46. **Deficiency/Recommendation:** Section 3.1.1.1.5, p. WP3-23, second paragraph

Samples from effluent springs and retention basin effluent were analyzed for "gross radiological characterization." The definition of "gross radiological characterization" should be provided. The analytical

method used and the significance of 45-year old data for the current extent of contamination should be explained.

47. Deficiency/Recommendation: Section 3.1.1.2, p. 3-23

The quantity of sludge in the fuel storage basin is noted in paragraph 2 as 23,000 pounds and in paragraph 4 as 110,000 pounds. What is the correct value? It appears that a units conversion error was made in paragraph 2.

48. Comment: Section 3.1.1.3.3., p. WP3-27

Reference given, "Ruppert 1953" is not in reference list.

49. Comment: Section 3.1.1.4.2, p. WP3-32

It should be noted in the text that the site was covered to grade in 1952 with clean soil.

50. Deficiency/Recommendation: Section 3.1.1.4.2, p. WP3-32

High concentrations of radionuclides were detected in the vicinity of the crib. The crib received highly contaminated water as a result of fuel cladding failures. Hence, information on the condition of the crib should be provided to help to determine whether the crib is a potential continuing source for the release of radionuclides to the environment.

51. Deficiency/Recommendation: Section 3.1.1.4.3, p. WP3-32, first paragraph

The text states, "The drain is buried at a depth of 20 feet . . . The site is presently marked by a 3-foot diameter, vitreous tile pipe that extends vertically through the ground surface." It is not clear whether a vertical drain is buried to a depth of 20 feet from ground surface or a lateral drain is buried at a depth of 20 feet with a drain extending vertically through the ground surface. It is also unclear whether the drain was deactivated and backfilled. These statements should be clarified.

52. Deficiency: Section 3.1.1.4.3, p. WP3-32, third paragraph

This paragraph does not address clearly the nature and extent of contamination using the results of analysis presented in Table 3-9. The text states that concentrations are less than 0.17 pCi/g for ⁶⁰Co, ¹⁵²Eu, ¹⁵⁵Eu, and ¹³⁷Cs. The sampling locations for these concentrations are not specified. Ranges of higher concentrations are reported for location B without specifying the radionuclide. Also, the values are incorrectly reported. At location B, the concentrations vary from 11 to 252 pCi/g for ¹⁵²Eu, from 40 to 510 pCi/g for ⁶⁰Co, and from 17 to 74 pCi/g for ¹³⁷Cs. Elevated levels of other radionuclides were also detected at location B.

Recommendation:

Clear and correct information should be provided from the existing data to help determine the nature and extent of contamination for further investigation.

53. **Deficiency/Recommendation:** Section 3.1.1.4.4, p. WP3-33

The location of the 116-F-3 fuel storage basin trench is not indicated in Figure 3-6 (sample locations near cribs and trenches) or elsewhere.

In this section, the text states that the site also received sludge from the F reactor fuel storage basin. However, there is no mention of the disposal of sludge from the fuel storage basin in earlier sections (Sections 2.1.6.1.2 and 3.1.1.2).

Very low levels of radionuclides were detected at this site because of sampling locations and depths. It is not clear whether the samples were collected in the vicinity of the inlet end of the trench to the basin. The trench depth was originally 8 feet and was later backfilled. Sampling below the backfill between 8 feet and 15 feet from the ground surface might have detected radionuclides. These data gaps should be addressed in this section.

54. **Deficiency/Recommendation:** Section 3.1.1.4.5, p. WP3-33

Results of analysis for one sample are incorrectly reported. The text states, "The sample collected from this boring indicated radionuclide concentrations of 0.027 to 0.54 pCi/g for ⁹⁰Sr, ¹³⁷Cs, ¹⁵⁴Eu, and ¹⁵⁵Eu at a depth of 10 feet." Table 3-9 indicates that radionuclide concentrations are 0.027 pCi/g, 0.54 pCi/g, 0.04 pCi/g, and 0.16 pCi/g for ⁹⁰Sr, ¹⁵⁴Eu, ¹³⁷Cs, and ¹⁵⁵Eu respectively.

It appears that a representative sample was not collected from the crib. A sample collected from below 10 feet from ground surface might have shown elevated levels of radionuclides. This data gap should be addressed.

55. **Comment:** Section 3.1.1.4.6, p. WP3-33

Other sources (i.e., Hanford Site Waste Management Units Report - Volume I, USDOE 1991) indicate that this structure is a french drain that was filled with gravel and covered with clean soil. The structure is marked by a vent pipe. This discrepancy should be addressed.

56. **Deficiency:** Section 3.1.1.4.7, p. WP3-33

It appears from Figure 3-6 that the sample (105-F-A) was collected at a distance of approximately 100 feet from the source (116-F-11, cushion corridor french drain). The sample is not representative for the source, which has a diameter of 3 feet and is 3 feet deep. This data gap is not addressed.

Recommendation:

The previous sampling location should be critically reviewed for representative sampling, and the data gap should be identified for further investigation.

57. **Deficiency/Recommendation:** Section 3.1.1.4.9, p. WP3-34

The location of 116-F-13 (experimental garden french drain) should be shown on Figure 3-6.

58. **Deficiency:** Section 3.1.1.5, p. WP3-34, second paragraph

The method of liquid waste disposal or discharge (e.g., through underground pipelines or drainage ditches) to the 116-F-1 Lewis canal from the F reactor building, 190-F building, and 189-F building is not described.

Recommendation:

The Lewis canal has received liquid wastes from three different buildings. Disposal of liquid waste to the canal should be described to help determine whether the liquid waste transfer pipes are potential sources of contamination.

59. **Comment:** Figure 3-7, p. WP3-35 and Section 3.1.1.5, p. WP3-34, third paragraph

The sample locations in the figure do not correspond to those in figure 3.4-5 in Dorian and Richards, nor do they correspond to the text. Correct the discrepancy.

60. **Deficiency/Recommendation:** Section 3.1.1.6, p. WP3-38

The section number is incorrectly reported and should be changed. The location of the unplanned release area (UN-100-F-1) should be indicated on a figure. The text should provide information on the removal of contaminated soil after the incident and any soil sampling performed, if appropriate.

61. **Comment:** Section 3.1.1.6.6, p. WP3-39

Reference given, "Encke 1989" is not in reference list.

62. **Deficiency:** Section 3.1.1.8, p. WP3-40

There is no map to locate the sources within the 100-FR-2 Operable Unit.

Recommendation:

A map should be included indicating the location of various solid waste burial areas within the 100-FR-2 Operable Unit with respect to the 100-

FR-1 Operable Unit in order to help determine whether the solid waste burial areas represent a potential contaminant source that may also adversely affect the 100-FR-1 Operable Unit.

63. Deficiency: Section 3.1.2.1, p. WP3-43

In this section and elsewhere (FSP-9+10), it is noted that sampling will be conducted to develop a 100-FR-1 background soil quality database. It is our understanding that a Hanford Site soil background database is already being developed for use on all Hanford CERCLA investigations. We also question expanding the background database to include organic chemicals. It is our understanding (with the possible exception of PCBs) that all hazardous organic chemicals found in Hanford soils are assumed to result from Hanford Site activities and are not considered part of natural background.

Recommendation:

Note the existence of the Hanford Site background program and coordinate all 100-FR-1 specific background soil sampling with the site-wide program to assure compatibility and avoid redundancy. Also, either delete references to organic chemicals to be included in the soil background database or justify their inclusion.

64. Comment: Section 3.1.2.1, p. WP3-46

The use of Hanford Site-wide data to construct groundwater water quality background may be misleading. The proximity of the 100-F Area to the Columbia River and the assumed mixing of river water and groundwater in at least some of the 100-F Area indicate that background for the 100-F Area will probably not equal background for the entire site.

65. Comment: Section 3.1.3.1, p. WP3-49

It is stated that pesticides, herbicides, and semivolatile organics have not been detected in 100-F Area wells. How many wells have been tested (and how many analyses done)? Provide sampling results verifying that these contaminants were analyzed for, but not detected.

66. Comment: Section 3.1.3.2.2, p. WP3-49

It is stated that tritium concentrations in 199-F5-6 appear to increase from 1976-80. There is no pattern of increase, only a one-time spike in 1980.

67. Comment: Figure 3-9; p. WP3-73

All of the 199-F5 wells are mislabeled as 199-FS wells.

68. Comment: Table 3-14C, p. WP3-82

Are there no data for well 699-77-36 for Sr-90 thru Zn?

69. Comment: Figure 3-10, p. WP3-83, and Section 3.1.3.2.2, p. WP3-49

It is stated that tritium peaked in well 199-F8-1 at approximately 30,000 pCi/L in 1985. The graph indicates a value closer to 40,000.

70. Comment: Figure 3-10, p. WP3-83

Wells 199-F5-1 and 199-F7-1 appear to have long-term tritium records; why not graph these?

71. Comment: Figure 3-11, p. WP3-84 and Table 2-2, p. WP2-33

Well 699-71-30 is included in figure 3-11, but no information is given in table 2-2.

72. Comment: Section 3.1.3.2.2, p. WP3-85

The statement that nitrate concentrations have shown an increase which peaked in the mid to late 1980s is not substantiated by figures 3-12, -13, and -14. Only well 199-F8-1 shows such a pattern.

73. Comment: Section 3.1.2.1.1, p. WP3-85

The nitrate plume shown in Eddy and Wilbur (1980) appears to be different than plumes shown for earlier and later years primarily due to a change in the contouring interval used. Otherwise, this plume is essentially the same as the others.

74. Comment: Section 3.1.3.2.2, p. WP3-85

Reference given, Eddy and Wilbur (1980) is not in the reference list.

75. Comment: Section 3.1.3.2.2, p. WP3-85

The comment that data from off-site wells indicate declining nitrate concentrations is not accurate. The only two "off-site" wells shown (figure 3-14) indicate increasing nitrate in one well (699-71-30) and decreasing nitrate in the other well (699-77-36). The only other nearby "off-site" wells with water-quality data that we can find are the cluster well (699-80-43P, -Q, -R, -S) and well 699-84-35A0, and these wells show no obvious nitrate trends.

76. Comment: Section 3.1.3.2.3, p. WP3-85, Figure 3-5, p. WP3-89, and Figure 3-16, p. WP3-90

The statement that gross beta concentrations are steadily declining in all wells may not be accurate. For most of the wells shown in figures 3-15 and 3-16, there are no data for the period of the late 1960s or mid-1970s to 1987. The trends over these periods are unknown. Recent data (1987-89) show a mixture of trends in the wells in adjacent to the 100-F Area.

77. **Deficiency:** Section 3.1.3.2.4, p. WP3-85

Table 3-14C lists strontium-90 at a maximum 297 pCi/L with a mean of 190 pCi/L in well 199-F5-3.

Recommendation:

Revise the text to correct this deficiency.

78. **Comment:** Figure 3-12, p. WP3-86

Wells 199-F5-1 and 199-F7-1 appear to have long-term nitrate records; why not graph these?

79. **Comment:** Figure 3-12, p. WP3-86 and Figure 3-13, p. WP3-87

The captions on these figures are reversed. Also, no units are shown for figure 3-13.

80. **Deficiency:** Section 3.1.7.1, p. WP3-110

The 126-F-1 ash disposal pit is listed as a primary source of groundwater contamination, yet it is not identified in Figure 3-1 (p. WP3-8) as a source. Also, Section 3.1.1.8.8 (p. WP3-42) states that analysis of the ash from this pit using the extraction procedure toxicity (EP-tox) test did not indicate the ash as a hazardous waste. The rationale for including the ash pit as a primary source should be explained.

The 116-F-3 storage basin trench is identified in the text (last paragraph) as the primary source of tritium contamination, yet this basin is not included in the bulleted list of primary sources in the earlier portions of this section.

Recommendation:

Provide a rationale for including the 126-F-1 ash disposal pit as a primary source even though the EP-tox test was negative. If the pit is a major source, it should be included in Figure 3-1. Reorganize Section 3.1.7.1 to include the 116-F-3 storage basin trench in the bulleted list of primary sources.

81. **Comment:** Section 3.1.7.2, p. WP3-112, first paragraph, last sentence

Delete parentheses and comma in paragraph.

82. **Comment:** Section 3.1.7.2, p. WP3-112, second paragraph, first sentence

This sentence is incomplete.

83. Comment: Section 3.1.7.3.1, p. WP3-114

The statement that groundwater flow is eastward and northeastward may be in error. Very few water-level data exist, but the best data set we could find (wells 199-F5-1, 699-70-23, 699-71-30, 699-77-36, 699-81-38, and 699-86-42; for December 6,7,8, 1988) indicate an eastward to southeastward flow direction. The available tritium data may support the north/northeast interpretation, however, the available nitrate data seem to support the east/southeast interpretation.

84. Comment: Section 3.1.7.3.1, p. WP3-114

It is stated that evidence exists for upward flow from the basalt (based on wells in 100-H Area). An additional set of wells (699-80-43P, -Q, -R, -S) may also yield evidence of upward flow. Are there any recent water-level data for this set of wells?

85. Comment: Section 3.2.1.2, p. WP3-122

The Model Toxics Control Act (WAC 173-340) should be listed in the State of Washington Requirements Section.

86. Deficiency: Section 3.3.2, p. WP3-136, first paragraph

The text indicates that risk calculations were performed according to EPA headquarters risk assessment guidance. However, example calculations are not provided.

Recommendation:

Example calculations should be provided for the risk estimates given in this section, including one calculation for a carcinogen and one calculation for a noncarcinogen via a specific pathway.

87. Deficiency: Section 3.3.4, WP3-136

Background risk is not a useful or appropriate concept to introduce under the heading of risk quantification.

The utilization of background risk in this section is misleading. It incorrectly implies that excess risks are not additive. It incorrectly implies that background risk is a threshold.

Recommendation:

Eliminate all reference to background risk from Section 3.3.4.

88. Deficiency/Recommendation: Section 3.3.4, p. WP3-136, first paragraph

The word "pagebreak" should be deleted. It appears to have been overlooked during editing.

89. **Deficiency:** Table 3-30, p. WP3-137

The exposure assumptions should address the most conservative scenario. For example a 16 kg. child may live on the site in a future residential scenario for a duration of exposure equal to 6 years. That child could potentially ingest 200 mg/day of soil per day.

Recommendation:

Revise the risk assessment to address the exposures listed above.

90. **Comment:** Table 3-31, p. WP3-138

The heading "Date" should be better defined.

91. **Comment:** Table 3-31, p. WP3-138

It is unclear why odor and task threshold are listed as the critical effects for ammonia.

92. **Deficiency:** Section 3.3.5, p. WP3-144

The discussion does not identify data needs brought to light by the preliminary risk assessment exercise. Identification of data needs would help in fashioning the investigation.

Recommendation:

The preliminary risk assessment exercise should identify data needs.

93. **Deficiency:** Section 3.4, p. WP3-148

The environmental assessment identifies a single study on the subject. With the brevity of discussion, this indicates a drastic need for a great deal of additional information before an environmental assessment can be completed. Yet, no specific needs are identified. Information is needed to explain past, present, and potential future effects on the environment. The singular conclusion that concentrations of radionuclides have been decreasing since 1971 is not an environmental assessment.

Recommendation:

Elaborate on past, present, and potential future environmental effects of past-practices. Identify data needed to make such an environmental assessment.

94. **Deficiency:** Section 3.5.1, p. WP3-149, third bullet

The point of compliance for groundwater contamination is the upper most level of the saturated zone extending vertically to the lowest depth that could potentially be effected by the site (WAC 173-340-720(6)(b)).

Recommendation:

Revise this objective to address the statement above.

95. **Deficiency:** Section 3.5.2, p. WP3-150

The text cites 40 CFR 300.68(f)(1)(V) in reference to the requirement of including the no-action alternative in the final list of proposed remedial alternatives. This reference is to the previous version of the National Contingency Plan (NCP), which has been superseded.

Recommendation:

While the requirement for the no-action alternative is unchanged in the new version of the NCP, there are several other important changes to the remedy selection process that should be incorporated in this work plan. The changes are found in 40 CFR 300.430(e)(3)-(6).

96. **Deficiency:** Section 3.5.3, Figure 3-21, p. WP3-152

This figure does not clearly indicate the preliminary general response actions, technologies, and process options available for soil, sediments, and groundwater. For example, the remedial technology "capping" is listed under the general response action of "disposal." Capping is not a disposal method; rather, it is a containment method.

Recommendation:

A separate figure for each medium should be included to indicate clearly the available preliminary general response actions, technologies, and process options, to help evaluate the appropriate technologies and process options for each medium. For example, coagulation/flocculation is not applicable for soil but is applicable for groundwater. Another example is vitrification, which is not applicable for groundwater but is applicable for soil.

97. **Comment:** Section 4.1.1, p. WP4-2, first paragraph, first sentence

The PNL facilities in F Area operated until 1976, therefore, the area has been inactive for 14 years.

98. **Comment:** Section 4.1.1.3, p. WP4-3

The threat from buried solid waste is dependent on the depth of burial. If the wastes are buried close to the water table or capillary fringe there could be a change of contaminant migration from seasonal highs in the water level. If the wastes are buried near surface, there is the possibility of direct contact by flora and fauna or of waste migration to the surface.

100. Comment: Section 4.1.2.2, p. WP4-6, second bullet

It is apparent from the drilling logs that the water table is around 30 feet. The shallow and deep vadose zone definitions should reflect the data.

101. Deficiency/Recommendation: Section 4.2.2, p. WP4-10

The text states, "New data will be collected to fill the data gaps identified above in Section 4.1.3." Section 4.1.3 does not exist. This discrepancy should be resolved.

102. Deficiency: Section 4.2.8, Table 4-3, WP4-17

One of the data types listed for collection is "Integrity of waste containment structures." Section 4.2.3, p. WP4-11 states, "There are no known containment devices that might fail and release substantial contamination to the environment." These two statements appear inconsistent.

Recommendation:

Specify which waste containment structures will have integrity testing and explain the rationale.

103. Comment: Section 4.2.12, p. WP4-26

Westinghouse, DOE, EPA, and Ecology are currently negotiating the development of an EII (EII 4.3) dealing specifically with investigation derived waste. It may be appropriate to note this in the text.

104. Comment: Section 5.1.4.6, p. WP5-17, second paragraph

It should be noted that samples will also be sent in for lab analysis independent of field screening results. Field screening techniques are not currently accurate enough to be used as exclusive criteria in determining contaminants, nor are they inclusive of all constituents of concern.

105. Deficiency: Section 5.1.5.2, p. WP5-18, last paragraph

The total number of samples sent off-site will depend on QA/QC requirements.

Recommendation:

Revise the text to include the QA/QC requirement.

106. **Comment:** Section 5.1.6, p. WP5-20, second paragraph

The PNL Facilities operated until 1976. It is unclear from the text to where contaminated water that had been discharged to the outfall was diverted.

107. **Comment:** Section 5.1.6, p. WP5-20

Information should be added regarding the most recent shoreline seepage study (Dirkes, 1990). Dirkes attempted to resample the 100-F seeps of McCormack and Carlile in 1988, but could not locate any seepage.

108. **Deficiency:** Section 5.1.11.2, p. WP5-29

The work plan is unclear as to how vadose zone physical characteristics will be used to evaluate contaminant migration. Section 5.1.11.2 generally describes how emphasis will be placed on defining partition coefficients for contaminants of concern between solid and liquid media at the site. Yet no mention is made as to how the processes controlling movement of the liquid media will be evaluated, nor does the work plan describe whether the RI will provide the necessary data to evaluate these processes.

Recommendation:

Describe what methods will be used to evaluate contaminant migration in the vadose zone. Specifically note analytical models to be used, describe their data requirements, and document that the appropriate data are being collected in the 100-FR-1 RI.

109. **Deficiency:** Section 5.1.11.3, p. WP5-30

Chemical, physical, and lethologic data are noted to be used as input into physical and chemical models. However, the specific models to be used are not described in the work plan. In designing a data collection program for use as input to mathematical models, it is important to evaluate the model to be sure that the appropriate input data are collected. It should also be noted that specific models have been selected for use in Hanford CERCLA investigations.

Recommendation:

Specifically describe the models proposed for use for 100-FR-1 groundwater data evaluation. Describe the data needs of the models and document that the appropriate data are being collected in the 100-FR-1 RI.

110. **Deficiency:** Section 5.1.12, p. WP5-31, first paragraph

The text states, "The baseline risk assessment will follow the guidance provided by EPA (1986a,b; . . .)." The 1986b reference is incorrect. In the reference list on p. WP8-11, the 1986b reference is numbered

"EPA/540/1-86/001" and entitled "Superfund Public Health Evaluation Manual." However, the correct title associated with EPA/540/1-86/001 is "Health Effects Assessment for Hexachloropentadiene."

Recommendation:

The references should be checked. The appropriate corrections in the text and in the reference list should be made. The overall approach to risk assessment should follow EPA (1989).

111. **Deficiency:** Section 5.1.12.2, p. WP5-32, third paragraph

The text discusses the identification and characterization of "maximally exposed individuals for a worst-case scenario." However, the current EPA position requires evaluation of a reasonable maximum exposure scenario rather than a worst-case scenario (EPA 1989, 1990a). The EPA believes that the reasonable maximum exposure scenario provides a more realistic assessment of risk.

Recommendation:

The words "worst-case" should be replaced with "reasonable maximum exposure." The baseline risk assessment should use reasonable exposure assumptions rather than worst-case assumptions.

112. **Deficiency:** Figure 5-1, p. WP5-33

The toxicity assessment box is incorrect. Although characterization of toxicity is appropriate in the toxicity assessment, identification of acceptable exposure levels is not part of toxicity assessment but is part of risk characterization.

Recommendation:

The words "Identify Acceptable Exposure Levels" should be removed from the toxicity assessment box.

113. **Deficiency:** Section 5.1.12.3, p. WP5-34, first paragraph

The text states, "The output of the toxicity assessment will be a qualitative description of the toxic properties of each contaminant and a quantitative index of each contaminant's acceptable exposure level." This objective is incorrect. Determination of acceptable levels is part of risk characterization, not part of the toxicity assessment. However, it is appropriate to present quantitative critical toxicity values, such as reference doses and slope factors, in the toxicity assessment.

Recommendation:

The words "acceptable exposure level" should be replaced with "critical toxicity values."

114. Deficiency/Recommendation: Section 5.1.12.3, p. WP5-34, third paragraph

The evaluation of ARARs is not part of the toxicity assessment or the baseline risk assessment. ARARs are used by risk managers during the feasibility study for decision-making purposes. This paragraph should be deleted.

115. Deficiency/Recommendation: Section 5.1.12.3, p. WP5-34, fourth paragraph

The text discusses determination of acceptable levels for contaminants. Determination of acceptable levels is part of risk characterization, not toxicity assessment. The discussion of acceptable levels should be removed.

116. Deficiency: Section 5.1.12.4, p. WP5-35, second paragraph

The Model Toxics Control Act (MTCA) sets the goal for exposure to carcinogens within the State of Washington at 10⁻⁵ to 10⁻⁶. This ARAR is more stringent than the Federal requirement and must be adhered to.

Recommendation:

Revise the goal of the risk characterization to be consistent with state law.

117. Comment: Section 5.4.3.8, p. WP5-50

State acceptance will be an integral part of selecting remedial action on this site. As the supporting agency, the State of Washington will be involved in all aspects of this site. This will also include formal concurrence of the Record of Decision by the director.

118. Deficiency: Attachment 1, Section 1.2, p. SAP-1, first paragraph

The reference to materials that have neither been approved by the regulators, nor included in the administrative record should be deleted. All field procedures must be contained in this sampling and analysis plan or the approved Environmental Investigations and Site Characterization Manual (WHC-CM-7-7).

119. Deficiency: Attachment 1, Section 1.0, p. FSP-2, first paragraph

See comment on SAP-1 above.

FIELD SAMPLING PLAN

120. Deficiency: Section 2.1, p. FSP-5

The subtask entitled "compilation and review of source data" belongs in the scoping portion of the work plan as an aid to focusing the sampling approach. Similar compilation and review tasks are proposed in sections 3.1 (source investigation), 4.1 (vadose zone investigation), 7.1 (air investigation), 8.1 (ecological investigation), and 9.1 (cultural resource investigation). These need not be separate tasks. Presumably, investigators will not review the records separately for each investigation.

Recommendation:

Clearly state in this section that based on the results of further compilation and review of existing information, sampling and analysis tasks may change. Also, combine all the tasks for compilation and review into a single task.

121. Deficiency/Recommendation: Section 2.3, p. FSP-6

It is not clear whether the entire area of the operable unit will be included in the surface radiation survey, or whether the 26 subunits identified as sources (Section 5.1, work plan) will be surveyed. Grid spacings that will be used for the surface radiation survey should be specified. Background plots should also be included.

122. Deficiency/Recommendation: Section 3.0, p. FSP-9, first paragraph

Source characterization sampling for the subunits that received high level radionuclide wastes is proposed at the margin or outside of the boundaries of these subunits to establish contaminants of concern and their concentrations. The proposed sampling approach should provide adequate data to determine the magnitude of contamination for remedy selection. Therefore, the subunits that received high level radionuclide wastes should be directly sampled.

123. Deficiency: Section 3.2, p. FSP-9 and FSP-10

The second and third paragraphs address subsoil sampling in the vadose zone from borings drilled for the installation of upgradient groundwater monitoring wells. It is unclear whether surface soil samples will be collected at the proposed sites. Also, only two boreholes are proposed for background sampling. It is virtually impossible to obtain meaningful data on soils from only two data points. The Washington Model Toxics Control Act states that 20 site-specific (area) background soil samples should be collected for this purpose (WAC173-340-708(11)(d)). Also, it is unclear how the collection of background soil data for the 100-FR-1 Operable Unit interfaces with the ongoing Hanford background studies.

Recommendation:

Increase the number of samples and discuss the role of background soil sampling at the 100-FR-1 Operable Unit in the Hanford background studies.

124. **Deficiency:** Section 3.3, p. FSP-10

The text states: "All samples will be screened in the field using both hand-held and mobile laboratory screening techniques." A description of or reference to the types of screening techniques is not included.

Numerous work plans have been initiated for other operable units at the Hanford site. Many of those operable units (especially others in the 100-area) have many of the same contaminants of concern in similar media. Therefore, a correlation between field screening and CLP laboratory results may have already been established and need not be prepared.

Recommendation:

Specify the type of field screening techniques proposed. Also, interface with the other 100-area investigations for the correlation between field and CLP data.

125. **Comment:** Table FSP-1, p. FSP-11

Why are no boreholes planned for 116-F-2? This site is listed on page WP5-2 as one of the 26 subunits identified as sources. According to table 3-3 on page WP3-10, 116-F-2 has the second highest radiation inventory (15 curies) of the subunits listed.

126. **Deficiency:** Figure FSP-1; p. FSP-18

The rationale for the sampling locations and sampling depths is not provided.

Recommendation:

The text should contain additional information on new source locations and proposed sampling depth and locations. The figure should also indicate the previous sampling locations to determine whether the proposed sampling locations are representative. The trench was originally 10 feet deep and backfilled with soil. However, no information is provided on the depth of the backfill material. Hence, the proposed sampling at depths of 8.5 feet and 11 feet may fail to detect the contaminants. Therefore, sample depths should be selected on the basis of previous investigations, backfill information, the type of effluent received, and the amount of effluent discharged.

127. **Deficiency:** Figure FSP-2, p. FSP-19

The length of the fuel storage basin trench is reported as 300 feet. However, in Section 3.1.1.4.4 (work plan), the length of the trench is reported as approximately 100 feet. This discrepancy should be corrected. The rationale for sample location, sample depth, and the number of samples is not provided. The proposed sampling of the backfill may fail to detect hot spots.

Recommendation:

Previous samples were collected at a depth of 18-20 feet, too deep to adequately characterize the source. Samples should be taken at three depths, close to the backfill.

128. **Deficiency:** Figure FSP-3, p. FSP-20

Sampling is proposed in the vicinity of the 116-F-4 pluto crib. No sampling of surface and near-surface soil is proposed.

Recommendation:

The rationale should be provided for the selection of sampling locations, sampling depths, and the number of samples. The crib should be directly sampled. Surface and near-surface samples should also be collected since it is possible that the crib may have been filled to capacity and these data may be critical for quantifying baseline risks.

129. **Deficiency:** Figure FSP-4, p. FSP-21

Construction information for the 116-F-5 ball washer crib are not provided. This information is needed to evaluate the sampling approach. The rationale for the sampling depths is not discussed.

Recommendation:

Additional samples should be collected at the surface, near-surface, and below the bottom of the crib to characterize the source.

130. **Deficiency:** Figure FSP-5, p. FSP-22

The rationale for the sampling locations, depths, and the number of samples is not provided for the 116-F-6 liquid waste disposal trench. Previous sampling efforts detected high levels of radionuclides at depths greater than those proposed (Table 3-9, work plan). Therefore, the proposed sampling approach may fail to determine the extent of contamination.

Recommendation:

The rationale should be provided for the sampling approach at the 116-F-6 trench. The sampling depth at the proposed locations should be increased to 20 feet, with at least 5-foot intervals below the bottom of the trench.

131. **Deficiency:** Figure FSP-6, p. FSP-23

There are inconsistencies in the crib name and depth. In Section 3.1.1.4.6 (work plan), the crib is named as seal pin water crib and the crib depth is shown as 10 feet. The rationale for the sampling depth is not provided. In addition, construction details of the 116-F-7 crib are not provided in the work plan.

Recommendation:

The discrepancies between the field sampling plan and the work plan should be clarified. Additional samples should be considered at the surface and near surface.

132. **Deficiency:** Figure FSP-7, p. FSP-24

It is unclear whether the 116-F-8 spillway and outfall structures are the same (Section 3.1.1.1.3, work plan). It is also unclear whether the proposed sampling approach is for the spillway or for the outfall structure.

Recommendation:

Clarification of the sampling approach should be provided. Additional information should be included on the rationale for the proposed sampling locations and sampling depths, and the current status of the spillway and outfall structures. Near-surface sampling from borehole BH20 should be considered.

133. **Deficiency:** Figure FSP-10, p. FSP-27

The rationale for the sampling location, sampling depth, and the number of samples is not provided for the 116-F-10 dummy decontamination french drain. It is not clear whether the proposed sampling location (BH27) is downgradient of the source. No surface or near-surface sampling is proposed.

Recommendation:

The proposed sampling location should be justified. The location should be downgradient and close to the source. Surface and near-surface samples should be considered.

134. **Comment:** Figure FSP-10, p. FSP-27

Is the 116-F-10 french drain too hot to drill through? If not, the planned borehole should be moved to the center of the drain.

135. **Deficiency:** Figures FSP-11, FSP-12, and FSP-13, pp. FSP-28, 29, and 30

No information is provided on the backfill materials for the drains 116-F-11, 116-F-12, and 116-F-13. Sampling of the backfill materials is not proposed.

Recommendation:

Since there is a potential for contamination of backfill materials, samples should be collected from the backfill materials.

136. **Deficiency/Recommendation:** Figure FSP-17, p. FSP-34

This figure is identical to Figure FSP-15 and should be omitted.

137. **Deficiency:** Section 3.3, p. FSP-35, second paragraph

The text states, "Samples will also be collected from the land portions of the discharge pipelines and structures to the Columbia River." Sampling locations, sampling intervals, and the number of samples are not specified. It is not clear whether soil samples will also be collected in the vicinity of the discharge pipelines.

Recommendation:

The sampling plan should include the method of sampling from the interior of the pipes, sampling locations, and the number of samples. If soil sampling is planned in the vicinity of the pipelines, then a map should be provided indicating the sampling locations, sampling depths, and number of samples.

138. **Deficiency:** Section 3.3, p. FSP-35, third paragraph

Surface soil sampling for polychlorinated biphenyls (PCBs) is proposed for the 151-F substation "... from areas with visible soil contamination." A past spill may not be visible from the surface. A map or reference to a map showing the location of the 151-F substation is not included in the text. It is unclear why PCBs are not included in the analytes listed in Table FSP-1.

Recommendation:

Cite Figure 2-1 in this section of the work plan, for the location of the 151-F substation. Provide the rationale for not analyzing for PCBs at other suspected sources.

139. **Recommendation:** Section 3.4, p. FSP-35

Migration of contaminants from the soil to groundwater is shown as a potential primary exposure pathway in figure 3-19. We must, therefore, be able to quantify the potential migration of contaminants in the soil column to groundwater, and this calculation will require knowledge of the soil physical and hydraulic characteristics. We suggest that soil physical and hydraulic characteristics be measured in samples taken from the source-sampling boreholes. The physical characteristics to be measured should include those listed in table FSP-3, as well as the relationships between moisture content and matric potential and moisture content and unsaturated hydraulic conductivity. These measurements should be made on soils taken from directly below the waste management units because the infiltration of large volumes of waste may have altered the physical and hydraulic properties of the soils in which the majority of residual contamination is found.

140. **Deficiency:** Section 3.4, p. FSP-35

The last sentence states: "U.S. EPA CLP Level 1 and Level 2 methods will be employed for mobile onsite laboratory analyses." However, Section 4.2.8 of the work plan (p. WP4-12), states that the EPA classification of analytical levels is not well suited for remedial investigations at the Hanford site. These statements are inconsistent.

Recommendation:

The EPA terms and definitions for levels of analytical methods should be used consistently throughout the work plan.

141. **Deficiency:** Attachment 1, Section 4.2, p. FSP-38, third paragraph

The text does not specify who will make the decision to increase or decrease the sampling frequency?

Recommendation:

Revise this paragraph to expand the discussion of changing the sampling frequency.

142. **Deficiency:** Figure FSP-18, p. FSP-48

The figure does not agree with Figures 3-7 and FSP-1. Previous sampling locations are not shown. No sampling is proposed along the curved portion of the canal. Even though previous sampling efforts indicate high levels of radionuclides at 3 feet from ground surface, no sampling plan of surface and near-surface soil is proposed.

Recommendation:

A consistent figure should be used for both source and vadose zone characterization at the 116-F-1 Lewis canal. The rationale for the sampling locations and depths should be provided, including the lack of surface soils.

143. Deficiency: Figure FSP-19, p. FSP-49

The fuel storage basin trench may have exceeded full capacity during a fuel cladding failure. This may have resulted in lateral movement of contaminants resulting in contamination of surface and near-surface soils in addition to subsurface soils. Surface and near-surface sampling is not proposed.

Recommendation:

Surface and near-surface soil samples should be collected since surface soils may be a potential exposure route. These data may be critical for quantifying baseline risks.

144. Deficiency: Figure FSP-20, p. FSP-50

The rationale for the borehole location is not provided. No sampling is proposed for surface and near-surface soils.

Recommendation:

Since the crib is small, contamination of surface and near-surface soils is likely. Hence, surface and near-surface soil samples should be collected.

145. Deficiency: Figure FSP-23, p. FSP-53

The crib depth is shown as 10 feet, while in Figure FSP-6 the crib depth is shown as 20 feet. Surface and near-surface sampling is not proposed.

Recommendation:

The crib depth should be corrected. Surface and near-surface soil samples should be collected to determine whether surface soils are also a potential exposure route.

146. Deficiency: Figures FSP-24 and FSP-25, pp. FSP-54 and FSP-55

The rationale for the proposed number of boreholes on one side of the spillway and PNL outfall structure and is not provided.

Recommendation:

Additional boreholes on the other side of the spillway and PNL outfall structure should be included in order to determine whether the contaminants have migrated. Sampling depths should be given for all boreholes.

147. **Deficiency:** Figures FSP-27, -28, -29, and -30, pp. FSP-57, -58, -59, and -60

The rationale for the sampling intervals is not provided.

Recommendation:

The proposed sampling depth intervals may fail to detect contamination. Sampling at an interval of 5 feet from the ground surface to the proposed depth at each drain should be considered.

148. **Comment:** Section 4.2, p. FSP-68, Number 5

Subcoring or paring samples to get a "fresh" sample for volatile organics is recommended.

149. **Comment:** Section 4.4, p. FSP-70

Stainless steel screens and casing are also used at Hanford. It should be explained how this would affect geophysical logging.

150. **Deficiency:** Attachment 1, Section 4.3, p. FSP-70, first paragraph

See comment on page SAP-1 above.

151. **Deficiency:** Section 4.5, p. FSP-72

In paragraph 2, it is noted that ground penetrating radar (GPR) is expected to provide poor results due to the coarse-grained nature of the Hanford formation. We disagree with this assumption. GPR has been shown to be generally successful in applications within Hanford formation sediments. The 300-FF-1 operable unit has similar Hanford formation soils with a large number of cobbles, and GPR has been successfully used to locate burial grounds and pipelines (Sandness, G.A., March 1991, Report on Geophysical Surveys in the 300-FF-1 Operable Unit: EMO-1032, 27 pages).

Recommendation:

We recommend that GPR be considered for use in 100-FR-1 for confirming the location of pipelines and for identifying the boundaries of burial grounds, etc. If there is documentation of unsuccessful of GPR in Hanford formation sediments, please provide us with a copy.

152. **Deficiency:** Section 4.6, p. FSP-73 and Table FSP-4

The text in Section 4.6 notes several reduction/oxidation pairs in table FSP-4. We find only one redox pair--ferric iron and ferrous iron--as well as dissolved oxygen. We question the need for measuring redox pairs in the vadose zone of the Hanford formation (a well drained soil with little known organic content or contamination), and we also question how dissolved oxygen of soil samples will be measured.

Recommendation:

We recommend re-evaluating table FSP-4 and clarifying Section 4.6. A few redox pairs may be useful at selected sites, but we question their measurement in all vadose samples. We also suggest that rather than proposing dissolved oxygen as an analyte, analyses for total organic carbon would provide more useful information.

153. **Deficiency:** Section 5.2, p. FSP-75

Nine single monitoring wells and four well clusters are described. However, it is not clear how (or if) the existing wells will be used.

Recommendation:

The existing wells should be examined for suitability as monitoring wells (including their usability after some form of rehabilitation/modification). If F2-2 or F2-3 are usable as monitoring wells (as is or after rehabilitation), then MW-3 may not be needed.

154. **Comment:** Figure FSP-37, p. FSP-76

The placement of cluster wells is reasonable for the assumed northeast flow direction. However, if flow is to the southeast (see comment on Section 3.1.7.3.1, p. WP3-14), a cluster will be needed near the southeast corner of the 100-F Area (i.e., southeast of MW-6/MW-8).

155. **Comment:** Figure FSP-37, p. FSP-76 and Figures FSP-39 thru 42, p. FSP-80 thru 83

The map indicates "cluster wells" C-1, C-2, C-3, and C-4. The well completion diagrams do not match the map:

1. Clusters C-1 and C-2 appear to be the "Northwest" and "Southwest" corner clusters.
2. There is no "Southeast" corner cluster on the map. Is this C-4?
3. There is no C-3 cluster diagram.

156. **Comment:** Attachment 1, Section 5.2, p. FSP-77

The detailed lab analysis must also include 10-20% of the samples for QA/QC.

The reason for the larger size casing is to allow for aquifer testing with subpumps, etc. If aquifer testing is not done the larger size casing may not be necessary. One advantage of the larger size casing is reduction in size if large cobbles are encountered.

157. **Deficiency:** Section 5.2, p. FSP-77

The stated minimum frequency of sampling (every 10 feet of borehole) is not sufficient.

Recommendation:

Minimum frequency should be every 5 feet.

158. **Deficiency:** Section 5.2, p. FSP-79

It is stated that all new boreholes and all existing wells will be logged (natural-gamma, gamma-gamma, neutron-neutron). It has been determined that gamma-gamma and neutron-neutron logs are not usable in the standard Hanford well installation (i.e., the existing wells). Also, it is not clear as to the type of casing that will be installed in the new wells; stainless steel, pvc, etc.? Also, no mention is made of the spectral-gamma tool presently being used at Hanford.

Recommendation:

Clearly state the intended casing material(s) for new boreholes. Remove the reference to gamma-gamma and neutron-neutron logging in those wells where these methods have been deemed inappropriate. Include spectral-gamma logging for all boreholes/wells.

159. **Comment:** Section 5.2, p. FSP-79 and Figure FSP-39, p. FSP-80

It is stated that pilot holes will be drilled at each cluster location to the basalt and that these holes will not be completed as wells. Figure FSP-39 does not show a pilot hole to the basalt and indicates that the pilot hole shown will be completed in the FSB unit.

160. **Comment:** Section 5.2.1.3, p. FSP-84

It should be noted that annular material will be tremmied into the hole.

161. **Comment:** Attachment 1, Section 5.2.1.5, p. FSP-85, second paragraph

This is a good idea, however, it is possible that it would cramp any 2 inch pump pipe.

162. **Deficiency:** Attachment 1, Section 5.3, p. FSP-85, second paragraph

Well development is not complete until they are developed to or below the 5 NTUs.

Recommendation:

Revise the text to include the 5 NTU requirement.

163. **Comment:** Section 5.4, p. FSP-86

Some monitoring wells should be equipped with recorders for selected water quality (e.g., temperature, specific conductance); in particular, wells in the area of influence of the Columbia River.

164. **Comment:** Section 5.5, p. FSP-86

A temporary water-level network should be started as soon as possible using the existing wells in and adjacent to the 100-F Area. This information could help guide the placement of monitoring wells, selection of screened intervals, etc. Some guidance regarding measuring frequency (monthly?, weekly?, continuous recorders?) could also be obtained from this network.

165. **Deficiency/Recommendation:** Section 5.6, p. FSP-88

The design of the aquifer tests are subject to the concurrence and approval of the regulatory authorities. We agree that it is premature to determine the details of such tests at this time. In other Hanford Site RI/FS work plans, detailed aquifer test plans are noted to be provided for review and approval by the regulatory authorities. We recommend that aquifer test plans be noted here as well.

166. **Comment:** Figure FSP-43, p. FSP-91

See comment on Section 3.1.7.3.1, p. WP3-114, regarding groundwater flow direction. If groundwater flow is to the southeast (rather than the northeast as described), then contaminated groundwater may have moved (or may still be moving) to the southeast and emerged as seepage downriver from the 100-F Area shoreline. Additional seep sampling sites will be needed (downriver from site SW/SS=10) if the southeastward flow direction is confirmed.

167. **Comment:** Attachment 1, Section 5.6, p. FSP-88

Single well tests can also be used as pumping tests.

168. **Deficiency:** Attachment 1, Section 6.4, p. FSP-94, last paragraph

See comment on page SAP-1 above.

- 169 **Deficiency:** Section 6.4, p. FSP-94, third paragraph

The first sentence states that field measurements will be made at each of the 17 river stations. The next sentence states that stream velocity measurements will be made. It is unclear at which of the 17 stations (any or all) velocity measurements will be made. Also, the purpose of the velocity measurements is unclear. Without river cross-section measurements, river discharge cannot be calculated.

Recommendation:

State the purpose and locations of river velocity measurements. If calculation of river discharge is the end result, state the purpose as the discharge measurements.

170. **Deficiency:** Attachment 1, Section 6.4, p. FSP-95, first paragraph

See comment on page SAP-1 above.

171. **Comment:** Section 8.2, p. FSP-98, fourth sentence

This sentence implies that herbivores will ultimately feed on carnivores and humans and should be reworded..

QUALITY ASSURANCE PROJECT PLAN

172. **Deficiency/Recommendation:** Distribution List, p. QAPP-v

The distribution list is blank. Complete the distribution list to include, at a minimum, those persons whose names appear on the approval page.

173. **Deficiency/Recommendation:** Section 3.1, p. QAPP-1

The project objective does not include supporting a risk assessment as specified in Task 12, p. QAPP-4. State that data resulting from the investigation will be used to support a quantitative baseline risk assessment.

174. **Deficiency:** Section 3.4.8, p. QAPP-3

Task 8, ecological investigation, describes sampling of terrestrial, riparian, and aquatic species and sample analysis. These activities, including the type of sample analyses to be conducted, are not mentioned elsewhere in the QAPP.

Recommendation:

Identify all ecological parameters to be measured and the measurement methods.

175. **Deficiency:** Section 5.0. p. QAPP-8

The definitions presented for data quality Levels I through V do not correspond to those presented in the EPA (1987b) reference document cited in the text. For example, for Level IV the text states "... CLP RAS methods shall be performed for [only] select analytes on the TCL and TAL . . . ," and Level III is described as having "... approximately the requirements of the CLP for Level IV . . ."

Recommendation:

The EPA definitions for data quality levels should be used. Additional specific information should be added to the EPA definitions. The intent of the EPA definitions should remain intact.

176. **Deficiency:** Table QAPP-1, p. QAPP-9 through QAPP-12

The following deficiencies are found in Table QAPP-1.

- The reference to the CLP is inappropriate for non-target compound list (TCL) compounds such as oxalate and sulfamate. CLP-equivalent special analytical service methods are not identified but are described as "to be determined."
- Incorrect versions of the CLP statements of work (SOWs) for analysis of organics and inorganics are presented.
- Relative percent difference limits, percent recovery limits, and the contract- required detection limits, which should be reviewed prior to approval, are not presented or adequately referenced for many of the parameters (see all "i" footnotes).
- Non-analytical methods are not included for review or referenced adequately (see all "h" footnotes).
- The analytical methods referenced for metals are incomplete.
- Not one method but two ("CLP" and "Methods for Chemical Analysis of Water and Wastes (1983b)") are listed for several parameters.
- Several methods are identified solely by number and are not referenced.
- Detection limits for many parameters, particularly general chemical parameters, are not specified and are described in the footnote as laboratory-specific.
- "NA," defined as "not applicable," is indicated for percent recovery limits where values exist or should be set (for example, for cyanide, sulfate, and phosphate).

Recommendation:

The individual parameters to be analyzed, methods to be used, relative percent difference limits, percent recovery limits, and required detection limits should be presented or fully referenced. Non-CLP methods for non-TCL and non-target analyte list (TAL) parameters that are to be analyzed as CLP-equivalent, or Level V, should be accompanied by a standard operating procedure. The standard operating procedure should include the proposed analytical method and criteria set to establish CLP equivalency.

177. Deficiency: Section 5.0, p. QAPP-8 through QAPP-13

None of the control limits for precision and accuracy or the parameter list detection limits, methods, or completeness goals for soil analyses are presented for review.

Recommendation:

A separate table addressing soil parameters should be included. If tissue samples are to be analyzed, as discussed in Task 8 on p. QAPP-3, a separate table is needed for those parameters also.

178. Deficiency: Attachment 1, Section 6.1.1, p. QAPP-14

See comment on page SAP-1 above.

179. Deficiency/Recommendation: Section 6.2.3, p. QAPP-15

The references for sample container requirements include only Westinghouse and U.S. Army Corps of Engineers documents. The EPA (1988a) guidance document should be cited and used for establishing sample container and handling criteria.

180. Deficiency: Table QAPP-3, p. QAPP-18

The methods listed in Table QAPP-3 are not properly referenced and are incorrect for several parameters. The CLP methods are not referenced to a SOW revision (EPA 1990c,d). The radionuclide method is identified as "Westinghouse." The footnote states "EPA methods are not defined for analysis of these parameters; Westinghouse is developing methods for use and agency approval." However, the methods are not presented in the QAPP for agency approval. The remaining methods appear to come from two EPA documents (1983b, 1986) that are not referenced. The methods listed for six of the parameters are for aqueous samples and are not appropriate for soil and sediment samples. Several container requirements, preservatives, and holding times are left blank. The footnote "EPA 1982" is incomplete and does not appear in Section 17.0, Reference. The TCL holding times do not agree with EPA (1990c).

Recommendation:

The methods presented should be properly referenced and appropriate for soil samples. The table should be completed. The containers, preservatives, and holding times should agree with EPA (1986, 1988a, 1990c,d) guidance. The most recent versions of the appropriate methods should be cited. All methods should be available for review in the QAPP or by accessible reference. Chromium should be identified as hexavalent chromium.

181 **Deficiency:** Table QAPP-4, p. QAPP-19

The methods listed in Table QAPP-4 are not properly referenced and are incorrect for several compounds. Six hundred-series methods are cited for TCL organic analyses. "Westinghouse" is identified as the method for three of the parameters, but these methods are not presented for agency review. The remaining methods appear to come from two documents (EPA 1983b, 1986) that are not referenced. "NA," which is not defined, is presented as a method. Cap types are not specified. Several parameters are left blank. The holding times for extractable organics are incomplete. The time from extraction to analysis is omitted. The footnote "EPA 1982" is incomplete and does not appear in Section 17.0, Reference.

Recommendation:

The methods presented should be properly referenced and appropriate for aqueous environmental samples. The table should be completed. The containers, preservatives, and holding times should agree with EPA (1986, 1988a, 1990c,d) guidance. The most recent versions of the appropriate methods should be cited. All methods should be available for review in the QAPP or by accessible reference.

182 **Deficiency/Recommendation:** Section 7.0, p. QAPP-22

Chain-of-custody procedures do not address the use of custody seals. Address the use of custody seals as described in EPA (1988a) documentation and provide an example custody seal.

183. **Deficiency:** Figure QAPP-2, p. QAPP-23

The space provisions on the example chain-of-custody form are inadequate. The analytical parameters are not identified, nor are there provisions for them.

Recommendation:

The chain-of-custody form should be redesigned to allow more space for remarks and tag numbers and to allow for identification of the analytical parameters. The chain-of-custody form should contain space for information as shown in the example presented in the CLP user's guide (EPA 1988a), Exhibit D, p. D-18.

184. **Deficiency:** Section 8.0, p. QAPP-25

The use of the term "validated analysis" is inappropriate. The use of this term is carried through the remainder of the QAPP. A data set, not an analysis, is validated. Also, until the validation is performed, the data are not validated. To refer to unvalidated data as "validated analysis" is technically unacceptable. The current text is not specific. The use of options is not appropriate. It is not stated who shall review and approve calibration criteria "defined by applicable standard analytical methods."

Recommendation:

Delete references to "validated analysis." Refer to data either by data quality level, by parameter group, or by method. Clearly reference the criteria to be used to perform laboratory instrument calibration for each of the various methods proposed. The calibration criteria should be specified by reference for each method or data type.

185. **Deficiency/Recommendation:** Section 9.0, p. QAPP-26

The text states that "analytical methods or procedures shall be selected or developed and approved." The analytical methods should be selected or developed prior to approval of the QAPP and initiation of site tasks. The information presented in Table QAPP-1 should include specific method detection limits, precision limits, and accuracy for each analyte of interest in each matrix. For each parameter in each matrix, the appropriate analytical method, detection limits, and quality control criteria for precision, accuracy, and completeness should be presented for review prior to approval of the QAPP.

186. **Deficiency:** Section 10.2, p. QAPP-27

It is inappropriate to have laboratory personnel ("subcontractor analytical laboratory" or "qualified independent reviewers within the laboratory generating the analysis") perform laboratory data validation.

Recommendation:

Third party personnel should perform the data validation. At a minimum, nonlaboratory personnel, such as U.S. Army Corps of Engineer personnel, or their contractors, should conduct the validation.

187. **Deficiency:** Section 10.2.1, p. QAPP-27

The term "specific validation report" appears to be used inappropriately in conjunction with Level II screening analyses.

Recommendation:

Very specific criteria, preferably in the form of a standard operating procedure, should be presented for performing data validation on Level II data prior to approval of the QAPP, if Level II data are to be validated.

188. Deficiency: Section 10.2.2, p. QAPP-28

Level III and Level IV data are addressed together in relation to data validation. The text indicates that both Level III methods and Level IV methods will be "validated" by the criteria specified in the EPA (1988b,c) validation guidelines. The text does not clearly specify the criteria to be used for each analytical method. The EPA (1988b,c) validation guidelines complement the CLP analyses and parameters and are not directly applicable to the Level III data as described in Section 5.0.

The statement, "validation reports shall be prepared documenting overchecks . . . as recommended in Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses" indicates inadequate data validation. Documenting "overchecks" does not constitute a detailed data validation. Section 10.0 does not state that TCL and TAL data will be validated in accordance with the EPA functional guidelines. Nor does Section 10.0 specify the criteria to be used to validate data generated by non-CLP methods. Only validation report writing is addressed in Section 10.0, not conducting data validation. The percent of data to undergo data validation is not specified.

Recommendation:

The appropriate criteria to be used in conducting data validation on Level III data should be presented. It should be clearly stated that CLP analyses, Level IV, will be validated in accordance with the criteria specified in the EPA (1988b,c) guidance documents. It is assumed that 100 percent of the Level II, III, IV, and V data will be validated.

189. Deficiency/Recommendation: Section 10.2.3, p. QAPP-29

Specific criteria for validating radionuclide data are not provided. Provide specific criteria, preferably in a standard operating procedure, for validating radionuclide data.

190. Deficiency/Recommendation: Section 10.4, p. QAPP-29

The term "remedial action" is used inappropriately. Delete "develop remedial" and insert "initiate corrective."

191. **Deficiency:** Section 11.0, p. QAPP-30

The term "validated analyses" is used inappropriately. The undefined term "shift" is used. The frequency of split-sample and blind sample collection is not specified. The reference to Chapter 12.0 is not adequate for frequency information.

Recommendation:

Delete "validated analyses" and insert "Level II, III, IV, and V data." Define "shift." State the frequency of split-sample and blind sample collection.

192. **Deficiency/Recommendation:** Section 11.0, p. QAPP-31, second paragraph

The term "where applicable" is used inappropriately. State the criteria to be used to decide what is applicable.

193. **Deficiency/Recommendation:** Section 11.0, p. QAPP-31

The term "whenever possible" is used inappropriately. State the criteria to be used to decide if duplicates are possible from a sample.

194. **Deficiency/Recommendation:** Section 12.0, p. QAPP-32

The text does not discuss audits but references various audit documents. Discuss the specifics regarding audits, such as performance frequency.

195. **Deficiency/Recommendation:** Section 14.0, p. QAPP-34

Define "applicable directions" and explain how they relate to risk assessments. Include criteria for deciding what is applicable.

196. **Deficiency/Recommendation:** Section 17.0, p. QAPP-37

The most current versions of the CLP SOWs are not cited. Replace the 1988 CLP SOW citations with the 1990 citations.

197. **Comment:** Section 2.2, p. HSP-15

The 4 foot depth for test pits is specific to shoring requirements. It may be necessary to consider pits of less than 4 feet as confined spaces requiring monitoring before entrance of personnel.

HEALTH AND SAFETY PLAN

198. Deficiency/Recommendation: Section 4.0, p. HSP-19, first paragraph

The bullet numbering is incorrect. The numbering begins with 2 rather than 1.

199. Deficiency/Recommendation: Section 5.0, p. HSP-24, fourth paragraph

The text indicates the standards to be used in determining critical levels. However, no Washington state standards are given. The appropriate Washington state standards should be included.

200. Deficiency/Recommendation: Section 6.0, p. HSP-26, first paragraph

The text indicates the standards to be used in determining the level of personal protective equipment. However, no Washington state standards are given. The appropriate Washington state standards should be included.

REFERENCES

- EPA, 1983a. Interim Guidelines and Specifications for Preparation of Quality Assurance Project Plans. QAMS-005/80. EPA-600/4-83-004. Office of Monitoring Systems and Quality Assurance, Office of Research and Development. U.S. Environmental Protection Agency, Office of Exploratory Research, Washington, D.C.
- EPA, 1983b. Methods for Chemical Analysis of Water and Waste. EPA-600/4-79-020. U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.
- EPA, 1986. Test Methods for Evaluating Solid Waste. SW-846, Third Edition. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.
- EPA, 1987a. Environmental Review Requirements for Removal Actions. OSWER Directive 9318.0-05. U.S. Environmental Protection Agency. April 13, 1987.
- EPA, 1987b. Data Quality Objectives for Remedial Response Activities: Volume I, Development Process. EPA/540/G-87/003. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.
- EPA, 1988a. User's Guide to the Contract Laboratory Program. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.
- EPA, 1988b. Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses. U.S. Environmental Protection Agency, Hazardous Site Evaluation Division, Washington, D.C.
- EPA, 1988c. Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses. U.S. Environmental Protection Agency, Hazardous Site Evaluation Division, Washington, D.C.
- EPA, 1989. Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A), Interim Final. EPA/540/1-89/002. U.S. Environmental Protection Agency. December 1989.
- EPA, 1990a. Statement of Work RI/FS Risk Assessment Deliverables - Region 10. U.S. Environmental Protection Agency. January 31, 1990.
- EPA, 1990b. Guidance for Data Usability in Risk Assessment. Interim Final. U.S. Environmental Protection Agency. EPA/540/G-90/008. October, 1990.

EPA, 1990c. U.S. Environmental Protection Agency Contract Laboratory Program, Statement of Work for Organic Analysis. Office of Solid Waste and Emergency Response, Washington, D.C.

EPA, 1990d. U.S. Environmental Protection Agency Contract Laboratory Program, Statement of Work for Inorganic Analysis. Office of Solid Waste and Emergency Response, Washington, D.C.

EPA, 1991. Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions. OSWER Directive 9355.0-30. U.S. Environmental Protection Agency. April 22, 1991.



April 18, 1991

Reply to
Attn. of: ES-098

MEMORANDUM

Subject: Use of Standard Default Exposure Factors

From: Pat Cirone, Chief *Pat Cirone*
Health and Environmental Assessment Section

To: Risk Assessors at State Agencies, ARCS and TES Contractors, others.
(Addresses)

The supplemental guidance document entitled "Standard Default Exposure Factors," (OSWER Directive No. 9285.6-03, March 25, 1991) provides specific exposure factors which are to be used in Superfund risk assessments to evaluate the following pathways:

- drinking water ingestion
- soil ingestion
- inhalation of volatiles/particulates
- consumption of homegrown produce, meat and milk
- consumption of locally caught fish.

The exposure factors are summarized on page 15 (the page that is not numbered) of the directive. The values in the directive supersede the RME values presented in the January, 1990, Region 10 "Statement of Work RI/FS Risk Assessment." (Questions about which values to use for projects already in progress should be directed to the EPA Remedial Project Manager or risk assessment contact person for the site.)

As stated on page one of the supplemental guidance, "the exposure factors presented in this document are generally considered most appropriate and should be used in baseline risk assessments unless alternate or site-specific values can be clearly justified by supporting data." Drinking water ingestion, soil ingestion, and inhalation defaults will apply to virtually all sites. The need to evaluate consumption of homegrown produce, meat and milk, and consumption of locally caught fish will be determined according to characteristics of each site. For these food chain pathways, it is also expected that site-specific or region-specific exposure factors will usually be preferable to defaults. Assessment of dermal exposures is not discussed in the directive. The "Guidance on Dermal Exposure Assessment" being developed by EPA ORD Exposure Assessment Group will address this pathway.

Users of the Standard Default Exposure Factors should understand that what is being "standardized," or made consistent, is the values describing human contact rates, exposure frequency, and duration of exposure. The directive does not comprehensively review methods of evaluating contaminant fate and transport or uptake into the food

chain. Although some examples of approaches or models for development of predicted exposure point concentrations are mentioned in the directive, the use of these models is not being mandated. In addition to the cited references, risk assessors should continue to consult other EPA national and regional guidance and the published literature for the most appropriate methods for predicting contaminant concentrations resulting from release from soil or water to air, uptake from soil into agricultural products, and uptake by fish from water or sediment.

Enclosure

Addresses:

David Bradley, Wash. Dept. of Ecology
Nigel Blakely, Wash. Dept. of Ecology
Lon Kissinger, Wash. Dept. of Ecology
Steven F. Cross, Wash. Dept. of Ecology
Harriet Ammann, Wash. Dept. of Health
Carol Sagerser, Wash. Dept. of Health
Don Oliver, Wash. Dept. of Health
Denise Laflamme, Wash. Dept. of Health
Rommell Rivera, Oregon DEQ
Aaron L. Bodor, Oregon DEQ
Paul Burnet, Oregon DEQ
Roseanne Lorenzana, Oregon Health Div.
Michael Heumann, Oregon Health Div.
Jane Gordon, Oregon Health Div.
Larry Foster, Oregon Health Dept.
Chuck Kleeburg, King. Co.
Anthony J. Bossart, King Co.
Shelley Kneip, King Co.
Doug Pierce, Pierce Co.
Norm Payton, Pierce Co.
Leslie Simmons, Alaska DEC
John Wakeman, Corps of Engineers
Ginny Dierich, Corps of Engineers
Janice Yonekura, Bechtel
David Lincoln, CH2M Hill
Lynn Gould, CH2M Hill
Dennis Shelton, CH2M Hill
Gerald L. Weinstein, E&E (Buffalo)
Yip Chün, E&E (Seattle)
Jon J. Bagby, E&E (Seattle)
Joyce Tsuji, ETI
Gary Pasco, ETI
Trudy Thomas, ETI
Margie Norman, ICF
Susan Turnblom, PRC
Audree DeAngeles, PRC
Roz Schoof, PTI
Celia Evans, PTI
Lisa Yost, PTI
Jim Elder, SAIC
David Maughn, SAIC
Priscilla Anderson, URS

Brad Grimsted, Weston
Rebecca Doe, Weston
Raleigh Farlow
Greg Glass
Allan Chartrand, Dames & Moore
Sue Robinson, EBASCO
Lonie Swenson, Golder
Clay Patmont, Hart Crowser
Julie Wilson, Landau
Lee Ann Sinagoga, NUS
Douglas Thelin, Corps
Lisa Gerhart, Woodward-Clyde
Perry Graves, Westinghouse
Yvonne McClellan, EG&G
Ines Figueroa, EG&G
Cheri Zehner, Parametrix
Jonathan Shields, Parametrix
John B. Collins, Beak
Ron Rathburn, Enviroscience
June Coover, RETEC
Elaine Faustman, UW



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

MAR 25 1991

OFFICE OF
SOLID WASTE AND EMERGENCY RESPONSE

OSWER Directive 9285.6-03

MEMORANDUM

SUBJECT: Human Health Evaluation Manual, Supplemental Guidance:
"Standard Default Exposure Factors"

FROM: Timothy Fields, Jr., Acting Director *Tim Fields*
Office of Emergency and Remedial Response

Bruce Diamond, Director *Bruce Diamond*
Office of Waste Programs Enforcement

TO: Director, Waste Management Division,
Regions I, IV, V, & VII
Director, Emergency & Remedial Response Division,
Region II
Director, Hazardous Waste Management Division,
Regions III, VI, VIII, & IX
Director, Hazardous Waste Division,
Region X

Purpose

The purpose of this directive is to transmit the Interim Final Standard Exposure Factors guidance to be used in the remedial investigation and feasibility study process. This guidance supplements the Risk Assessment Guidance for Superfund: Human Health Evaluation Manual, Part A that was issued October 13, 1989.

Background

An intra-agency workgroup was formed in March 1990 to address concerns regarding inconsistencies among the exposure assumptions used in Superfund risk assessments. Its efforts resulted in a June 29, 1990, draft document entitled "Standard Exposure Assumptions". The draft was circulated to both technical and management staff across EPA Regional Offices and within Headquarters. It was also discussed at two EPA-sponsored meetings in the Washington, D.C., area. The attached interim final document reflects the comments received as well as the results of recent literature reviews addressing inhalation rates, soil ingestion rates and exposure frequency estimates.



MAR 25 1991

NOTE TO: Addressees

This is an "advanced" copy of the "Standard Default Exposure Factors" guidance. Additional copies will be available to Agency and State personnel through the Superfund Document Center by writing:

Superfund Document Center (OS-240)
US EPA
401 M. Street, SW
Washington, DC 20460

or, by sending an E-mail message to:

OERR/PUBS
EPA 5248

The document will be available to the general public through NTIS.

911122-20718

OSWER DIRECTIVE: 9285.6-03

March 25, 1991

RISK ASSESSMENT GUIDANCE FOR SUPERFUND
VOLUME I: HUMAN HEALTH EVALUATION MANUAL

SUPPLEMENTAL GUIDANCE

"STANDARD DEFAULT EXPOSURE FACTORS"

INTERIM FINAL

Office of Emergency and Remedial Response
Toxics Integration Branch
U.S. Environmental Protection Agency
Washington, D.C. 20460
(202) 475-9486

ACKNOWLEDGEMENTS

This guidance was developed by the Toxics Integration Branch (TIB) of EPA's Office of Emergency and Remedial Response, Hazardous Site Evaluation Division. Janine Dinan of TIB provided overall project management and technical coordination in the later stages of its development under the direction of Bruce Means, Chief of TIB's Health Effects Program.

TIB would like to acknowledge the efforts of the interagency work group chaired by Anne Sergeant of EPA's Exposure Assessment Group in the Office of Health and Environmental Assessment. Workgroup members, listed below, and Regional staff provided valuable input regarding the content and scope of the guidance.

Glen Adams, Region IV
Lisa Askari, Office of Solid Waste
Alison Barry, OERR/HSCD
Steve Caldwell, OERR/HSED
David Cooper, OERR/HSCD
Linda Cullen, New Jersey Department of Environmental Protection
Steve Ells, OWPE/CED
Kevin Garrahan, OHEA/EAG
Susan Griffin, OERR/TIB
Gerry Hiatt, Region IX
Russ Kinerson, OHEA/EAG
Jim LaVelle, Region VIII
Mark Mercer, OERR/HSCD
Sue Norton, OHEA/EAG
Andrew Podowski, Region V
John Schaum, OHEA/EAG
Leigh Woodruff, Region X

TABLE OF CONTENTS

	Page
1.0 Introduction	1
1.1 Background	2
1.2 Present and Future Land Use Considerations	3
2.0 Residential	5
2.1 Ingestion of Potable Water	5
2.2 Incidental Ingestion of Soil and Dust	6
2.3 Inhalation of Contaminated Air	6
2.4 Consumption of Homegrown Produce	7
2.5 Subsistence Fishing	8
3.0 Commercial/Industrial	9
3.1 Ingestion of Potable Water	9
3.2 Incidental Ingestion of Soil and Dust	9
3.3 Inhalation of Contaminated Air	10
4.0 Agricultural	10
4.1 Farm Family Scenario	10
4.1.1 Consumption of Homegrown Produce	11
4.1.2 Consumption of Animal Products	11
4.2 Farm Worker	12

1.0 INTRODUCTION

The Risk Assessment Guidance for Superfund (RAGS) has been divided into several parts. Part A, of the Human Health Evaluation Manual (HHEM; U.S. EPA, 1989a), is the guidance for preparing baseline human health risk assessments at Superfund sites. Part B, now in draft form, will provide guidance on calculating risk-based clean-up goals. Part C, still in the early stages of development, will address the risks associated with various remedial actions.

The processes outlined in these guidance manuals are a positive step toward achieving national consistency in evaluating site risks and setting goals for site clean-up. However, the potential for inconsistency across Regions and among sites still remains; both in estimating contaminant concentrations in environmental media and in describing characteristics and behaviors of the exposed populations.

Separate guidance on calculating contaminant concentrations is currently being developed in response to a number of inquiries from both inside and outside the Agency. The best method for calculating the reasonable maximum exposure (RME) concentration for different media has been subject to a variety of interpretations and is considered an important area where further guidance is needed.

This supplemental guidance attempts to reduce unwarranted variability in the exposure assumptions used to characterize potentially exposed populations in the baseline risk assessment. This guidance builds on the technical concepts discussed in HHEM Part A and should be used in conjunction with Part A. However, where exposure factors differ, values presented in this guidance supersede those presented in HHEM Part A.

Inconsistencies among exposure assumptions can arise from different sources: 1) where risk assessors use factors derived from site-specific data; 2) where assessors must use their best professional judgement to choose from a range of factors published in the open literature; and 3) where assessors must make assumptions (and choose values) based on extremely limited data. Part A encourages the use of site-specific data so that risks can be evaluated on a case-by-case basis. This supplemental guidance has been developed to encourage a consistent approach to assessing exposures when there is a lack of site-specific data or consensus on which parameter value to choose, given a range of possibilities. Accordingly, the exposure factors presented in this document are generally considered most appropriate and should be used in baseline risk assessments unless alternate or site-specific values can be clearly justified by supporting data.

other programs within the Agency, for their review and comment. It was also presented and discussed at two EPA/OERR sponsored meetings. The meetings, facilitated by Clean Sites, Inc., brought members of the "Superfund community" and the Agency together to focus on technical issues in risk assessment.

A final review draft was distributed on December 5, 1990, which reflected earlier comments received as well as the results of more recent literature reviews addressing inhalation rates, soil ingestion rates and exposure frequency estimates (these being areas commented on most frequently).

1.2 PRESENT AND FUTURE LAND USE CONSIDERATIONS

The exposure scenarios, presented in this document, and their corresponding assumptions have been developed within the context of the following land use classifications: residential, commercial/industrial, agricultural or recreational. Unfortunately, it is not always easy to determine actual land use or predict future use: local zoning may not adequately describe land use; and unanticipated or even planned rezoning actions can be difficult to assess. Also, the definition of these zones can differ substantially from region to region. Thus, for the purposes of this document, the following definitions are used:

Residential

Residential exposure scenarios and assumptions should be used whenever there are or may be occupied residences on or adjacent to the site. Under this land use, residents are expected to be in frequent, repeated contact with contaminated media. The contamination may be on the site itself or may have migrated from it. The assumptions in this case account for daily exposure over the long term and generally result in the highest potential exposures and risk.

Commercial/Industrial

Under this type of land use, workers are exposed to contaminants within a commercial area or industrial site. These scenarios apply to those individuals who work on or near the site. Under this land use, workers are expected to be routinely exposed to contaminated media. Exposure may be lower than that under the residential scenarios, because it is generally assumed that exposure is limited to 8 hours a day for 250 days per year.

2.0 RESIDENTIAL

Scenarios for this land use should be evaluated whenever there are homes on or near the site, or when residential development is reasonably expected in the future. In determining the potential for future residential land use, the RPM should consider: historical land use; suitability for residential development; local zoning; and land use trends. Exposure pathways evaluated under this scenario routinely include, but may not be limited to: ingestion of potable water; incidental ingestion of soil and dust; inhalation of contaminated air; and, where appropriate, consumption of home grown produce.

2.1 Ingestion of Potable Water

This pathway assumes that adult residents consume 2 liters of water per day, 350 days per year, for 30 years.

The value of 2 liters per day for drinking water is currently used by the Office of Water in setting drinking water standards. It was originally used by the military to calculate tank truck requirements. In addition, 2 liters happens to be quite close to the 90th percentile for drinking water ingestion (U.S. EPA, 1990), and is comparable to the 8 glasses of water per day historically recommended by health authorities.

The exposure frequency (EF) of 365 days/year for the residential setting used in RAGS Part A has been argued both inside and outside of the Agency as being too conservative for RME estimates. National travel data were reviewed to determine if an accurate number of "days spent at home" could be calculated. Unfortunately, conclusions could not be drawn from the available literature; as it presents data on the duration of trips taken for pleasure, but not the frequency of such trips (OECD, 1989; Goeldner and Duea, 1984; National Travel Survey, 1982-89). However, the Superfund program is committed to moving away from values that represent the "worst possible case." Thus, until better data become available, the common assumption that workers take two weeks of vacation per year can be used to support a value of 15 days per year spent away from home (i.e., 350 days/year spent at home).

In terms of exposure duration (ED), the resident is assumed to live in the same home for 30 years. In the EFH, this value is presented as the 90th-percentile for time spent at one residence. (Please note that in the intake equation, averaging time (AT) for exposure to non-carcinogenic compounds is always equal to ED; whereas, for carcinogens a

In cases where the residential water supply is contaminated with volatiles, the assessor needs to consider the potential for exposure during household water use (e.g., cooking, laundry, bathing and showering). Using the same time-use/activity level data described above, a total of 15 m³/day was found to represent a reasonable upper-bound inhalation rate for daily, indoor, residential activities. Methods for modeling volatilization of contaminants in the household (including the shower) are currently being developed by J.B. Andelman and U.S. EPA's Exposure Assessment Group. Assessors should contact the Superfund Health Risk Assessment Technical Support Center for help with site-specific evaluations (FTS-684-7300).

2.4 Consumption of Home Grown Produce

This pathway need not be evaluated for all sites. It may only be relevant for a small number of compounds (e.g., some inorganics and pesticides) and should be evaluated when the assessor has site-specific information to support this as a pathway of concern for the residential setting.

The EFH presents figures for "typical" consumption of fruit (140 g/day) and vegetables (200 g/day) with the "reasonable worst case" proportion of produce that is homegrown as 30 and 40 percent, respectively. This corresponds to values of 42 g/day for consumption of homegrown fruit and 80 g/day for homegrown vegetables. They are derived from data in Pao, et al. (1982) and USDA (1980). EFH also provides data on consumption of specific homegrown fruits and vegetables that may be more appropriate for site-specific evaluations. Although sampling data are much preferred, in their absence plant uptake of certain organic compounds can be estimated using the procedure described in Briggs, et al. (1982). No particular procedure is recommended for quantitatively assessing inorganic uptake at this time; however, the following table developed by Sauerbeck (1988) provides a qualitative guide for assessing heavy metal uptake into a number of plants:

3.0 COMMERCIAL/INDUSTRIAL

Occupational scenarios should be evaluated when land use is (or is expected to be) commercial/industrial. In general, these scenarios address a 70-kg adult who is at work 5 days a week for 50 weeks per year (250 days total). The individual is assumed to work 25 years at the same location (95th-percentile; Bureau of Labor Statistics, 1990). This scenario also considers ingestion of potable water, incidental ingestion of soil and dust, and inhalation of contaminated air.

Please note that under mixed-use zoning (e.g., apartments above storefronts), certain pathways described for the residential setting should also be evaluated.

3.1 Ingestion of Potable Water

Until data become available for this pathway, it will be assumed that half of an individual's daily water intake (1 liter out of 2) occurs at work. All water ingested is assumed to come from the contaminated drinking water source (i.e., bottled water is not considered). For site-specific cases where workers are known to consume considerably more water (e.g., those who work outdoors in hot weather or in other high-activity/stress environments), it may be necessary to adjust this figure.

A lower ingestion rate is used in this pathway so that a more reasonable exposure estimate may be made for workers ingesting contaminated water. However, it is important to remember that remedial actions are often based on returning the contaminated aquifer to maximum beneficial use; which generally means achieving levels suitable for residential use.

3.2 Incidental Ingestion of Soil and Dust

In the occupational setting, incidental ingestion of soil and dust is highly dependent on the type of work being performed. Office workers would be expected to contact much less soil and dust than someone engaged in outdoor work such as construction or landscaping. Although no studies were found that specifically measured the amount of soil ingested by workers in the occupational setting, the one study that measured adult soil ingestion included subjects that worked outside of the home (Calabrese, et al., 1990a). Although the study had a limited number of subjects (n=6) and did not associate the findings with any particular activity pattern, it is the only study that did not rely on modeling to

4.1.1 Consumption of Homegrown Produce

The values used in evaluating this pathway are the same as those presented in Section 2.4. While it is more likely for farm families to cultivate fruits and vegetables, it is not necessarily true that they would be able to grow a sufficient variety to meet all their dietary needs and tastes. Thus, the consumption rate default values will be 42 g/day and 80 g/day for fruits and vegetables, respectively. Again, EFH presents consumption rates for specific homegrown fruits and vegetables. The assessor is reminded that the plant uptake pathway is not relevant for all contaminants and sampling of fruits and vegetables is highly recommended. However, in the absence of analytical data, plant uptake of organic chemicals can be estimated using the procedure described in Briggs, et al. (1982). No particular procedure is recommended for quantitatively assessing inorganic uptake at this time; however, the table (presented in Section 2.4) developed by Sauerbeck (1988) provides a qualitative guide for assessing heavy metal uptake into a number of plants.

4.1.2 Consumption of Animal Products

Animal products should only be addressed if it is known that local residents produce them for home consumption or are expected to do so in the future. The best way to determine which items are produced is by interviews or consultation with the local County Extension Service which usually has data on the type and quantity of local farm products.

EFH provides average ingestion rates for beef and dairy products and assumes that the farm family produces 75 percent of what it consumes from these categories. This corresponds to a "reasonable worst case" consumption rate of 75 g/day for beef and 300 g/day for dairy products. Although sampling data are much preferred, in their absence the procedure described in Travis and Arms (1988) may be used to estimate organic contaminant concentrations in beef and milk. This procedure does not provide transfer coefficients for poultry and eggs. Thus, the latter two pathways can be evaluated only if site-specific concentrations for poultry and eggs are available, or if transfer coefficients can be obtained from the literature.

Additional references addressing potential exposures from contaminated foods are listed in Section 2.0.

When evaluating this pathway please consider the possibility of subsistence fishing. Unlike the residential scenario, exposure estimates from this pathway would not necessarily be added to any other exposure estimates (see Section 2.5). Instead, it would be included as an estimate of exposure for a sensitive sub-population.

5.2 Additional Recreational Scenarios

A number of commentors requested standard default values for the following recreational scenarios: hunting, dirtbiking, swimming and wading. One approach to address exposure during swimming and wading is presented in HHEM Part A. The Agency is currently involved in research projects designed to estimate dermal uptake of contaminants from soil, water and sediment. Results of these studies will be used to update the swimming and wading scenarios as well as other scenarios that rely on estimates of dermal absorption. Unfortunately, lack of data and problems in estimating exposure frequencies and durations based on regional variations in climate have precluded the standardization of other recreational scenarios at this time. Additional guidance will be developed as data become available.

SUMMARY OF STANDARD DEFAULT EXPOSURE FACTORS (1)

Land Use	Exposure Pathway (2)	Daily Intake Rate	Exposure Frequency	Exposure Duration	Body Weight
Residential	Ingestion of Potable Water	2 liters	350 days/year	30 years	70 kg
	Ingestion of Soil and Dust	200 mg (child) 100 mg (adult)	350 days/year	6 years 24 years	15 kg (child) 70 kg (adult)
	Inhalation of Contaminants	20 cu.m (total) 15 cu.m (indoor)	350 days/year	30 years	70 kg
Commercial/ Industrial	Ingestion of Potable Water	1 liter	250 days/year	25 years	70 kg
	Ingestion of Soil and Dust	50 mg	250 days/year	25 years	70 kg
	Inhalation of Contaminants	20 cu.m/workday	250 days/year	25 years	70 kg
Agricultural	Ingestion of Potable Water	2 liters	350 days/year	30 years	70 kg
	Ingestion of Soil and Dust	200 mg (child) 100 mg (adult)	350 days/year	6 years 24 years	15 kg (child) 70 kg (adult)
	Inhalation of Contaminants	20 cu.m (total) 15 cu.m (indoor)	350 days/year	30 years	70 kg
	Consumption of Homegrown Produce	42 g (fruit) 80 g (veg.)	350 days/year	30 years	70 kg
Recreational	Consumption of Locally Caught Fish	54 g	350 days/year	30 years	70 kg

- (1) - Factors presented are those that should generally be used to assess exposures associated with a designated land use. Site-specific data may warrant deviation from these values; however, use of alternate values should be justified and documented in the risk assessment report.
- (2) - Listed pathways may not be relevant for all sites and, other exposure pathways may need to be evaluated due to site conditions. Additional pathways and applicable default values are provided in the text of this guidance.

7.0 REFERENCES

- Briggs, G., R. Bromilow, and A. Evans. 1982. Relationship between lipophilicity and root uptake and translocation of non-ionized chemicals by barley. *Pesticide Science* 13:495-504.
- Bureau of Labor Statistics. 1990. Statistical summary: tenure with current employer as of January 1987. (Transmitted via facsimile, 7 September 1990)
- Calabrese, E.J., Barnes, R., Stanek, E.J., Pastides, H., Gilbert, C.E., Veneman, P., Wang, X., Lasztity, A., and P.T. Kosteck. 1989. How Much Soil Do Young Children Ingest: An Epidemiologic Study. *Reg. Tox. and Pharmac.* 10:123-137.
- Calabrese, E.J., Stanek, E.J., Gilbert, C.E., and R.M. Barnes. 1990a. Preliminary Adult Soil Ingestion Estimates: Results of a Pilot Study. *Reg. Tox. and Pharmac.* 12:88-95.
- Calabrese, E.J. 1990b. Personal communication with J. Dinan, Toxics Integration Branch. EPA/OSWER/OERR. October 24, 1990.
- Cowherd, C., Muleski, G., Englehart, P., and D. Gillette. 1985. Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination. Prepared by Midwest Research Institute, Washington, D.C. for EPA/OHEA. EPA-600/8-85-002.
- Davis, S., Waller, P., Buschbom, R., Ballou, J. and P. White. 1990. Quantitative Estimates of Soil Ingestion in Normal Children between the Ages of 2 and 7 Years: Population-based Estimates Using Aluminum, Silicon and Titanium as Soil Tracer Elements. *Arc. Environ. Health.* 45(2):112-122.
- Goeldner, C.R. and K.P. Duea. 1984. Travel Trends in the United States and Canada. Business Research Division, University of Colorado at Boulder.
- Hawley, J.K. 1985. Assessment of health risk from exposure to contaminated soil. *Risk Analysis* 5(4):289-302.
- Hwang, S.T., and J.W. Falco. 1986. Estimation of Multimedia Exposures Related to Hazardous Waste Facilities. In: Cohen (ed.). *Pollutants in a Multimedia Environment*. New York, NY: Plenum Publishing Corp. pp. 229-264.
- National Travel Survey. 1982-1989. U.S. Travel Data Center, Washington, D.C.

ATTACHMENT A

ACTIVITY SPECIFIC INHALATION RATES

Background

The standard default value of 20 m³/day has been used by EPA to represent an average daily inhalation rate for adults. According to EFH, this value was developed by the International Commission on Radiologic Protection (ICRP) to represent a daily inhalation rate for "reference man" engaged in 16 hours of "light activity" and 8 hours of "rest". EPA (1985) reported on a similar study that indicated the average inhalation rate for a man engaged in the same activities would be closer to 13 m³/day. EFH, in turn, reiterated the findings of ICRP and EPA (1985) then calculated a "reasonable worst case" inhalation rate of 30 m³/day. This reasonable worst case value was used in Part A of the Human Health Evaluation Manual as the RME inhalation rate for residential exposures.

Commentors from both inside and outside the Agency expressed concerns that this value may be too conservative. Many also added their concern that exposure values calculated using this inhalation rate would not be comparable to reference doses (RfD) and cancer potency factors (q1*) values based on an inhalation rate of 20 m³/day. Thus, the Toxics Integration Branch of Superfund (TIB) conducted a review of the literature to determine the validity of using 30 m³/day as the RME inhalation rate for adults. Members of EPA's Environmental Criteria Assessment Office-Research Triangle Park (A. Jarabek, 9/20/90) and the Science Advisory Board (10/26/90) have suggested that inhalation rates could be calculated using time-use/activity level data reported in the "Development of Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessments" (OHEA; U.S. EPA, 1985). Thus, TIB used this data to calculate an RME inhalation rate for both the residential and occupational settings, as follows.

Methodology

- o The time-use/activity level data reported by OHEA (1985) were analyzed for each occupation subgroup;
- o The data were divided into hours spent at home vs. hours spent at the workplace (lunch hours spent outside of work and hours spent in transit were excluded);
- o The hourly data were subdivided into hours spent indoors vs. outdoors (to allow for estimating exposures to volatile contaminants during indoor use of potable water);

ATTACHMENT B

ESTIMATING ADULT SOIL INGESTION IN THE COMMERCIAL/INDUSTRIAL SETTING

Most of the available soil ingestion studies focus on children in the residential setting; however, two studies were found that address adult soil ingestion that also have application to the commercial/industrial setting (Hawley, 1985; Calabrese, et al., 1990).

Hawley (1985) used a number of assumptions for contact rates and body surface area to estimate the amount of soil and dust adults may ingest during a variety of residential activities. For indoor exposures, Hawley estimated levels based on contact with soil/dust in two different household areas, as follows: 0.5 mg/day for daily exposure in the "living space"; and 110 mg/day for cleaning dusty areas such as attics or basements. For outdoor exposures, Hawley estimated a soil ingestion rate during yardwork of 480 mg/day. The assumptions used to model exposures in the residential setting may also be applied to similar situations in the workplace. The amount of soil and dust adults contact in their houses may be similar to the amount an office or indoor maintenance worker would be expected to contact. Likewise, the amount of soil contacted by someone engaged in construction or landscaping may be more analogous to a resident doing outdoor yardwork.

Calabrese, et al. (1990) conducted a pilot study that measured adult soil ingestion at 50 mg/day. Although the study has several drawbacks (e.g., a limited number of participants and no information on the participants daily work activities), it included subjects that worked outside the home. It is also interesting to note that this measured value falls within the range Hawley (1985) estimated for adult soil ingestion during indoor activities.

From these studies, 50 mg/day was chosen as the standard default value for adult soil ingestion in the workplace. It was chosen primarily because it is a measured value but also because it falls within the range of modeled values representing two widely different indoor exposure scenarios. The 50 mg/day value is to be used in conjunction with an exposure frequency of 250 days/year and an exposure duration of 25 years. For certain outdoor activities in the commercial/industrial setting (e.g., construction or landscaping), a soil ingestion rate of 480 mg/day may be used; however, this type of work is usually short-term and is often dictated by the weather. Thus, exposure frequency would generally be less than one year and exposure duration would vary according to site-specific construction/maintenance plans.



Ground-Water Issue

CHARACTERIZING SOILS FOR HAZARDOUS WASTE SITE ASSESSMENTS

R. P. Breckenridge¹, J. R. Williams², and J. F. Keck¹

INTRODUCTION

The Regional Superfund Ground Water Forum is a group of ground-water scientists representing EPA's Regional Offices, organized to exchange up-to-date information related to ground-water remediation at hazardous waste sites. Soil characterization at hazardous waste sites is an issue identified by the forum as a concern of CERCLA decision-makers.

To address this issue, this paper was prepared through support from EMSL-LV and RSKERL, under the direction of R. P. Breckenridge, with the support of the Superfund Technical Support Project. For further information contact Ken Brown, EMSL-LV Center Director, at FTS 545-2270 or R. P. Breckenridge at FTS 583-0757.

Site investigation and remediation under the Superfund program is performed using the CERCLA remedial investigation/feasibility study (RI/FS) process. The goal of the RI/FS process is to reach a Record of Decision (ROD) in a timely manner. Soil characteriza-

tion provides data types required for decision making in three distinct RI/FS tasks:

1. Determination of the nature and extent of soil contamination.
2. Risk assessment, and determination of risk-based soil clean-up levels.
3. Determination of the potential effectiveness of soil remediation alternatives.

Identification of data types required for the first task, determination of the nature and extent of contamination, is relatively straightforward. The nature of contamination is related to the types of operations conducted at the site. Existing records, if available, and interviews with personnel familiar with the site history are good sources of information to help determine the types of contaminants potentially present. This information may be used to shorten the list of target analytes from the several hundred contaminants of concern in the 40 CFR Part 264 list (Date 7-1-89). Numerous guidance documents are available for planning all

¹ Idaho National Engineering Laboratory, Environmental Science and Technology Group, Idaho Falls, ID 83415.

² Soil Scientist, U.S. EPA/R. S. Kerr Environmental Research Laboratory, Ada, OK 74820



Superfund Technology Support Center for Monitoring and Site Characterization, Environmental Monitoring Systems Laboratory Las Vegas, NV

Superfund Technology Support Center for Ground-Water Fate and Transport, Robert S. Kerr Environmental Research Laboratory Ada, OK

Technology Innovation Office
Office of Solid Waste and Emergency Response
U.S. EPA, Washington, D.C.

Walter W. Kovalick, Jr., Ph.D., Director



Printed on Recycled Paper

aspects of the subsequent sampling effort (US EPA, 1987a, 1988a, 1988b, and Jenkins et al., 1988).

The extent of contamination is also related to the types of operations conducted at the site. Existing records, if available, and interviews with personnel familiar with the site history are also good sources of information to help determine the extent of contamination potentially present. The extent of contamination is dependent on the nature of the contaminant source(s) and the extent of contaminant migration from the source(s). Migration routes may include air, via volatilization and fugitive dust emissions; overland flow; direct discharge; leachate migration to ground water and surface runoff and erosion. Preparation of a preliminary site conceptual model is therefore an important step in planning and directing the sampling effort. The conceptual model should identify the most likely locations of contaminants in soil and the pathways through which they move.

The data type requirements for tasks 2 and 3 are frequently less well understood. Tasks 2 and 3 require knowledge of both the nature and extent of contamination, the environmental fate and transport of the contaminants, and an appreciation of the need for quality data to select a viable remedial treatment technique.

Contaminant fate and transport estimation is usually performed by computer modeling. Site-specific information about the soils in which contamination occurs, migrates, and interacts with, is required as input to a model. The accuracy of the model output is no better than the accuracy of the input information.

The purpose of this paper is to provide guidance to Remedial Project Managers (RPM) and On-Scene Coordinators (OSC) concerning soil characterization data types required for decision-making in the CERCLA RI/FS process related to risk assessment and remedial alternative evaluation for contaminated soils. Many of the problems that arise are due to a lack of understanding the data types required for tasks 2 and 3 above. This paper describes the soil characterization data types required to conduct model based risk assessment for task 2 and the selection of remedial design for task 3. The information presented in this paper is a compilation of current information from the literature and from experience combined to meet the purpose of this paper.

EMSL-Las Vegas and RSKERL-Ada convened a technical committee of experts to examine the issue and provide technical guidance based on current scientific information. Members of the committee were Joe R. Williams, RSKERL-Ada; Robert G. Baca, Robert P. Breckenridge, Alan B. Crockett, and John F. Keck from the Idaho National Engineering Laboratory, Idaho Falls, ID; Gretchen L. Rupp, PE, University of Nevada-Las Vegas; and Ken Brown; EMSL-LV.

This document was compiled by the authors and edited by the members of the committee and a group of peer reviewers.

Characterization of a hazardous waste site should be done using an integrated investigative approach to determine quickly and cost effectively the potential health effects and appropriate response measures at a site. An integrated approach involves consideration of the different types and sources of contaminants, their fate as they are transported through and are partitioned, and their impact on different parts of the environment.

CONCERNS

This paper addresses two concerns related to soil characterization for CERCLA remedial response. The first concern is the applicability of traditional soil classification methods to CERCLA soil characterization. The second is the identification of soil characterization data types required for CERCLA risk assessment and analysis of remedial alternatives. These concerns are related, in that the Data Quality Objective (DQO) process addresses both. The DQO process was developed, in part, to assist CERCLA decision-makers in identifying the data types, data quality, and data quantity required to support decisions that must be made during the RI/FS process. *Data Quality Objectives for Remedial Response Activities: Development Process* (US EPA, 1987b) is a guidebook on developing DQOs. This process as it relates to CERCLA soil characterization is discussed in the Data Quality Objective section of this paper.

Data types required for soil characterization must be determined early in the RI/FS process, using the DQO process. Often, the first soil data types related to risk assessment and remedial alternative selection available during a CERCLA site investigation are soil textural descriptions from the borehole logs prepared by a geologist during investigations of the nature and extent of contamination. These boreholes might include installation of ground-water monitoring wells, or soil boreholes. Typically, borehole logs contain soil lithology and textural descriptions, based on visual analysis of drill cuttings.

Preliminary site data are potentially valuable, and can provide modelers and engineers with data to begin preparation of the conceptual model and perform scoping calculations. Soil texture affects movement of air and water in soil, infiltration rate, porosity, water holding capacity, and other parameters. Changes in lithology identify heterogeneities in the subsurface (i.e., low permeability layers, etc.). Soil textural classification is therefore important to contaminant fate and transport modeling, and to screening and analysis of remedial alternatives. However, unless collected properly, soil textural descriptions are of limited value for the following reasons:

1. There are several different systems for classification of soil particles with respect to size. To address this problem it is important to identify which system has been or will be used to classify a soil so that data can be properly compared. Figure 1 can be used to compare the different systems (Gee and Bauder, 1986). *Keys to Soil Taxonomy* (Soil Survey Staff, 1990) provides details to one of the more useful systems that should be consulted prior to classifying a site's soils.
2. The accuracy of the field classification is dependent on the skill of the observer. To overcome this concern RPMs and OSCs should collect soil textural data that are quantitative rather than qualitative. Soil texture can be determined from a soil sample by sieve analysis or hydrometer. These data types are superior to qualitative description based on visual analysis and are more likely to meet DQOs.
3. Even if the field person accurately classifies a soil (e.g., as a silty sand or a sandy loam), textural descriptions do not afford accurate estimations of actual physical properties required for modeling and remedial alternative evaluation,

such as hydraulic conductivity. For example, the hydraulic conductivity of silty-sand can range from 10^{-5} to 10^{-1} cm/sec (four orders of magnitude).

These ranges of values may be used for bounding calculations, or to assist in preparation of the preliminary conceptual model. These data may therefore meet DQOs for initial screening of remedial alternatives, for example, but will likely not meet DQOs for detailed analysis of alternatives.

DATA QUALITY OBJECTIVES

EPA has developed the Data Quality Objective (DQO) process to guide CERCLA site characterization. The relationship between CERCLA RI/FS activities and the DQO process is shown in Figure 2 (US EPA, 1988c, 1987a). The DQO process occurs in three stages:

- **Stage 1. Identify Decision Types.** In this stage the types of decisions that must be made during the RI/FS are identified.

The types of decisions vary throughout the RI/FS process, but in general they become increasingly quantitative as the process proceeds. During this stage it is important to identify and involve the data users (e.g. modelers, engineers, and scientists), evaluate available data, develop a conceptual site model, and specify objectives and decisions.

- **Stage 2. Identify Data Uses/Needs.** In this stage data uses are defined. This includes identification of the required data types, data quality and data quantity required to make decisions on how to:

- Perform risk assessment
- Perform contaminant fate and transport modeling
- Identify and screen remedial alternatives

- **Stage 3. Design Data Collection Program.** After Stage 1 and 2 activities have been defined and reviewed, a data collection program addressing the data types, data quantity (number of samples) and data quality required to make these decisions needs to be developed as part of a sampling and analysis plan.

Although this paper focuses on data types required for decision-making in the CERCLA RI/FS process related to soil contamination, references are provided to address data quantity quality issues.

Data Types

The OSC or RPM must determine which soil parameters are needed to make various RI/FS decisions. The types of decisions to be made therefore drive selection of data types. Data types required for RI/FS activities including risk assessment, contaminant fate and transport modeling and remedial alternative selection are discussed in Soil characteristics Data Types Required for Modeling Section, and the Soil Characterization Data Type Required for Remedial Alternative Selection Section.

Data Quality

The RPM or OSC must decide "How good does the data need to be in order for me to make a given decision?". EPA has assigned quality levels to different RI/FS activities as a guideline. *Data Quality Objectives for Remedial Response Activities* (US EPA, 1987a) offers guidance on this subject and contains many useful references.

Data Quantity

The RPM or OSC must decide "How many samples do I need to determine the mean and standard deviation of a given parameter at a given site?", or "How does a given parameter vary spatially across the site?". Decisions of this type must be addressed by statistical design of the sampling effort. The *Soil Sampling Quality Assurance Guide* (Barth et al., 1989) and *Data Quality Objectives for Remedial Response* (US EPA, 1987a) offer guidance on this subject and contain many useful references.

PARTICLE SIZE LIMIT CLASSIFICATION				
	USDA	CSSC	ISSS	ASTM (unified)
0.0002		FINE CLAY		
0.001	CLAY	COARSE CLAY	COARSE CLAY	
0.002		FINE SILT		
0.003				
0.004				
0.006		MEDIUM SILT	SILT	
0.008				
0.01				
0.02		COARSE SILT		
0.03				
0.04				
0.06	VERY FINE SAND	VERY FINE SAND	FINE SAND	
0.08				
0.1				
0.2	FINE SAND	FINE SAND		FINE SAND
0.3				
0.4	MEDIUM SAND	MEDIUM SAND		
0.6				
0.8	COARSE SAND	COARSE SAND	COARSE SAND	MEDIUM SAND
1.0	VERY COARSE SAND	VERY COARSE SAND		
2.0				
3.0	FINE GRAVEL			COARSE SAND
4.0				
6.0				
8.0				
10		GRAVEL		FINE GRAVEL
20				
30	COARSE GRAVEL		GRAVEL	COARSE GRAVEL
40				
60				
80	COBBLES	COBBLES		COBBLES

USDA - U.S. DEPARTMENT OF AGRICULTURE, (SOIL SURVEY STAFF, 1975)

CSSC - CANADA SOIL SURVEY COMMITTEE (McKEAGUE, 1978)

ISSS - INTERNATIONAL SOIL SCI. SOC. (YONG AND WARKENTIN, 1966)

ASTM - AMERICAN SOCIETY FOR TESTING & MATERIALS (ASTM, D-2487, 1985a)

Figure 1. Particle-size limits according to several current classification schemes (Gee and Bauder, 1986).

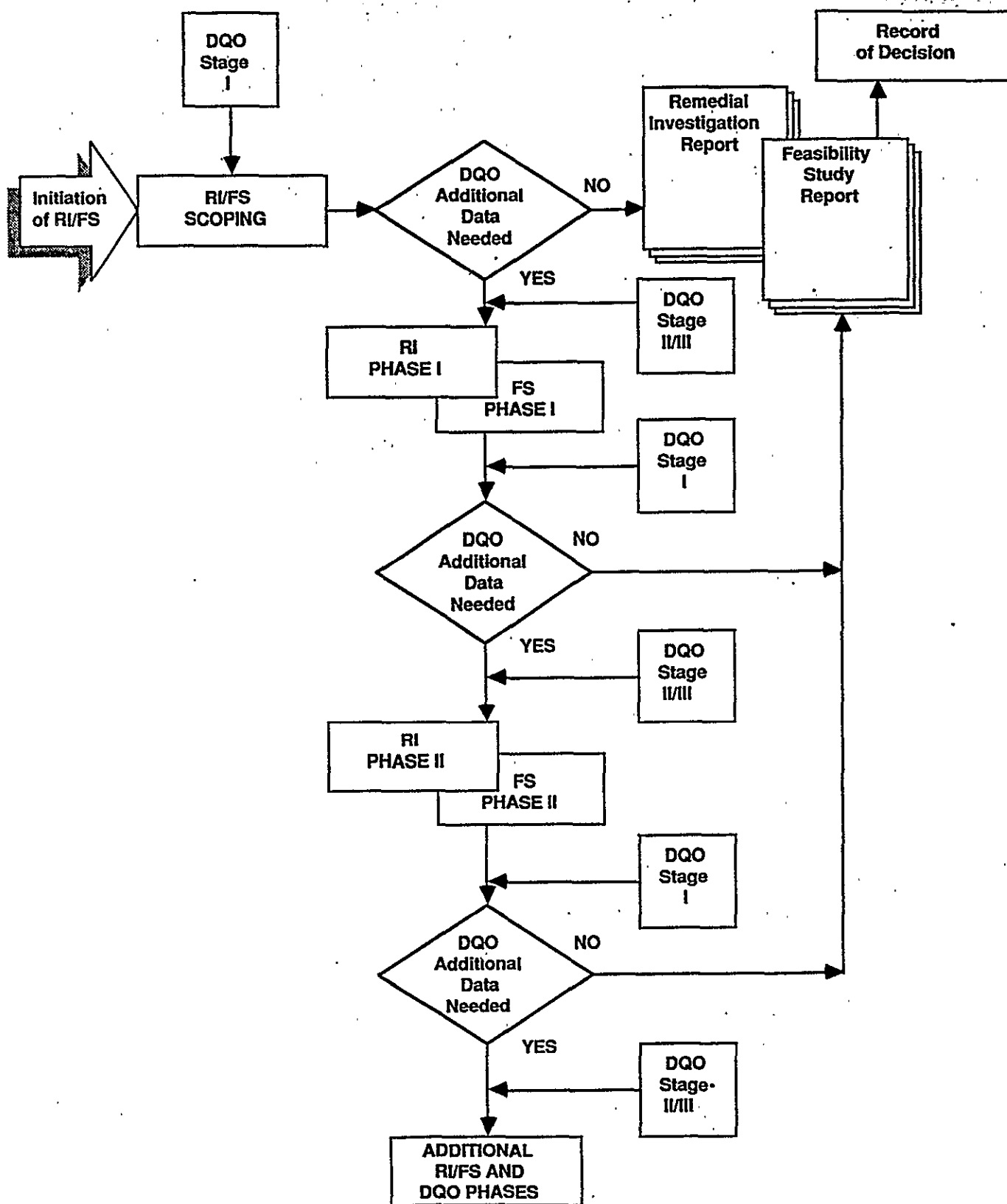


Figure 2. Phased R/FS approach and the DQO process (EPA, 1987a).

IMPORTANT SOIL CHARACTERISTICS IN SITE EVALUATION

Tables 1 and 2 identify methods for collecting and determining data types for soil characteristics either in the field, laboratory, or by calculation. Soil characteristics in Table 1 are considered the primary indicators that are needed to complete Phase I of the RI/FS process. This is a short, but concise list of soil data types that are needed to make CERCLA decisions and should be planned for and collected early in the sampling effort. These primary data types should allow for the initial screening of remedial treatment alternatives and preliminary modeling of the site for risk assessment. Many of these characteristics can be obtained relatively inexpensively during periods of early field work when the necessary drilling and sampling equipment are already on site. Investigators should plan to collect data for all the soil characteristics at the same locations and times, soil boring is done to install monitoring wells. Geophysical logging of the well should also be considered as a cost effective method for collecting lithologic information prior to casing the well. Data quality and quantity must also be considered before beginning collection of the appropriate data types.

The soil characteristics in Table 2 are considered ancillary only because they are needed in the later stages and tasks of the DQO process and the RI/FS process. If the site budget allows, collection of these data types during early periods of field work will improve the database available to make decisions on remedial treatment selection and model-based risk assessments. Advanced planning and knowledge of the need for the ancillary soil characteristics should be factored into early site work to reduce overall costs and the time required to reach a ROD. A small additional investment to collect ancillary data during early site visits is almost always more cost effective than having to send crews back to the field to conduct additional soil sampling.

Further detailed descriptions of the soil characteristics in Tables 1 and 2 can be found in *Fundamentals of Soil Physics and Applications of Soil Physics* (Hillel, 1980) and in a series of articles by Dragun (1988, 1988a, 1988b). These references provide excellent discussions of these characteristics and their influence on water movement in soils as well as contaminant fate and transport.

SOIL CHARACTERISTICS DATA TYPES REQUIRED FOR MODELING

The information presented here is not intended as a review of all data types required for all models, instead it presents a sampling of the more appropriate models used in risk assessment and remedial design.

Uses of Vadose Zone Models for Cercla Remedial Response Activities

Models are used in the CERCLA RI/FS process to estimate contaminant fate and transport. These estimates of contaminant behavior in the environment are subsequently used for:

- **Risk assessment.** Risk assessment includes contaminant release assessment, exposure assessment, and determining risk-based clean-up levels. Each of these activities requires estimation of the rates and extents of contaminant movement

in the vadose zone, and of transformation and degradation processes.

- **Effectiveness assessment of remedial alternatives.** This task may also require determination of the rates and extents of contaminant movement in the vadose zone, and of rates and extents of transformation and degradation processes. Technology-specific data requirements are cited in the Soil Characterization Data Type Required for Remedial Alternative Selection Section.

The types, quantities, and quality of site characterization data required for modeling should be carefully considered during RI/FS scoping. Several currently available vadose zone fate and transport models are listed in Table 3. Soil characterization data types required for each model are included in the table. Model documentation should be consulted for specific questions concerning uses and applications.

The Superfund Exposure Assessment Manual discusses various vadose zone models (US EPA, 1988e). This document should be consulted to select codes that are EPA-approved.

Data Types Required for Modeling

Soil characterization data types required for modeling are included in Tables 1 and 2. Most of the models are one- or two-dimensional solutions to the advection-dispersion equation, applied to unsaturated flow. Each is different in the extent to which transformation and degradation processes may be simulated; various contaminant release scenarios are accommodated; heterogeneous soils and other site-specific characteristics are accounted for. Each, therefore, has different data type input requirements.

All models require physicochemical data for the contaminants of concern. These data are available in the literature, and from EPA databases (US EPA, 1988c,d). The amount of physicochemical data required is generally related to the complexity of the model. The models that account for biodegradation of organics, vapor phase diffusion and other processes require more input data than the relatively simpler transport models.

Data Quality and Quantity Required for Modeling

DQOs for the modeling task should be defined during RI/FS scoping. The output of any computer model is only as valid as the quality of the input data and code itself. Variance may result from the data collection methodology or analytical process, or as a result of spatial variability in the soil characteristic being measured.

In general, the physical and chemical properties of soils vary spatially. This variation rarely follows well defined trends; rather it exhibits a stochastic (i.e., random) character. However, the stochastic character of many soil properties tends to follow classic statistical distributions. For example, properties such as bulk density and effective porosity of soils tend to be normally distributed (Campbell, 1985). Saturated hydraulic conductivity, in contrast, is often found to follow a log-normal distribution. Characterization of a site, therefore, should be performed in such a manner as to permit the determination of the statistical characteristics (i.e., mean and variance) and their spatial correlations.

(Continued on page 8)

**TABLE 1. MEASUREMENT METHODS FOR PRIMARY SOIL CHARACTERISTICS
NEEDED TO SUPPORT CERCLA DECISION-MAKING PROCESS**

Soil Characteristic*	Measurement Technique/Method (w/Reference)		
	Field	Laboratory	Calculation or Lookup Method
Bulk density	Neutron probe (ASTM, 1985), Gamma radiation (Blake and Hartage, 1986, Blake, 1965).	Coring or excavation for lab analysis (Blake and Hartage, 1986).	Not applicable.
Soil pH	Measured in field in same manner as in laboratory.	Using a glass electrode in an aqueous slurry (ref. EPRI EN-6637) Analytical Method - Method 9045, SW-846, EPA.	Not applicable.
Texture	Collect composite sample for each soil type. No field methods are available, except through considerable experience of "feeling" the soil for an estimation of % sand, silt, and clay.	ASTM D 522-63 Method for Particle Analysis of Soils. Sieve analysis better at hazardous waste sites because organics can effect hydrometer analysis (Kuate, 1986).	Not applicable.
Depth to ground water	Ground-water monitoring wells or piezometers using EPA approved methods (EPA 1985a).	Not applicable.	Not applicable.
Horizons or stratigraphy	Soil pits dug with backhoe are best. If safety and cost are a concern, soil bores can be collected with either a thin wall sample driver and veilmayer tube (Brown et al., 1990).	Not applicable.	May be possible to obtain information from SCS soil survey for the site.
Hydraulic conductivity (saturated)	Auger-hole and piezometer methods (Amoozeger and Warrick, 1986) and Guelph permeameter (Reynolds & Elrick, 1985; Reynolds & Elrick, 1986).	Constant head and falling head methods (Amoozeger and Warrick, 1986).	Although there are tables available that list the values for the saturated hydraulic conductivity, it should be understood that the values are given for specific soil textures that may not be the same as those on the site.
Water retention (soil water characteristic curves)	Field methods require a considerable amount of time, effort, and equipment. For a good discussion of these methods refer to Bruce and Luxmoore (1986).	Obtained through wetting or drainage of core samples through a series of known pressure heads from low to high or high to low, respectively (Klute, 1986).	Some look-up and estimation methods are available, however, due to high spatial variability in this characteristic they are not generally recommended unless their use is justified.
Air permeability and water content relationships	None	Several methods have been used, however, all use disturbed soil samples. For field applications the structure of soils are very important. For more information refer to Corey (1986).	Estimation methods for air permeability exist that closely resemble the estimation methods for unsaturated hydraulic conductivity. Example models those developed by Brooks and Corey (1964) and van Genuchten (1980).
Porosity (pore volume)		Gas pycnometer (Danielson and Sutherland, 1986).	Calculated from particle and bulk densities (Danielson and Sutherland, 1986).
Climate	Precipitation measured using either Sacramento gauge for accumulated value or weighing gauge or tipping bucket gauge for continuous measurement (Finkelstein et al., 1983; Kite, 1979). Soil temperature measured using thermocouple.	Not applicable.	Data are provided in the Climatic Atlas of the United States or are available from the National Climatic Data Center, Asheville, NC Telephone (704) 259-0682.

* Soil characteristics are discussed in general except where specific cases relate to different waste types (i.e., metals, hydrophobic organics or polar organics).

**TABLE 2. MEASUREMENT METHODS FOR ANCILLARY SOIL PARAMETERS
NEEDED TO SUPPORT CERCLA DECISION-MAKING PROCESS**

Soil Characteristic*	Measurement Technique/Method (w/Reference)		
	Field	Laboratory	Calculation or Lookup Method
Organic carbon	Not applicable.	High temperature combustion (either wet or dry) and oxidation techniques (Powell et al., 1989) (Powell, 1990).	Not applicable.
Capacity Exchange Capacity (CEC)	See Rhoades for field methods.	(Rhoades, 1982).	
Erodibility			Estimated using standard equations and graphs (Israelsen et al., 1980) field data for slope, field length, and cover type required as input. Soils data can be obtained from the local Soil Conservation Service (SCS) office.
Water erosion Universal Soil Loss Equation (USLE) or Revised USLE (RUSLE)	Measurement/survey of slope (in ft rise/ft run or %), length of field, vegetative cover.	Not applicable.	A modified universal soil loss equation (USLE) (Williams, 1975) presented in Mills et al., (1982) and US EPA (1988d) source for equations.
Wind erosion	Air monitoring for mass of containment. Field length along prevailing wind direction.	Not applicable.	The SCS wind loss equation (Israelsen et al., 1980) must be adjusted (reduced) to account for suspended particles of diameter $\leq 10\mu\text{m}$ Cowherd et al., (1985) for a rapid evaluation (≤ 24 hr) of particle emission from a Superfund site.
Vegetative cover	Visual observation and documented using map. USDA can aid in identification of unknown vegetation.	Not applicable.	
Soil structure	Classified into 10 standard kinds – see local SCS office for assistance (Soil Survey Staff, 1990) or Taylor and Ashcroft (1972), p. 310.	Not applicable.	See local soil survey for the site.
Organic carbon partition coefficient (K_{oc})	<i>In situ</i> tracer tests (Freeze and Cherry, 1979).	(ASTM E 1195-87, 1988)	Calculated from K_{ow} , water solubility (Mills et al., 1985; Sims et al., 1986).
Redox couple ratios of waste/soil system	Platinum electrode used on lysimeter sample (ASTM, 1987).	Same as field.	Can be calculated from concentrations of redox pairs or O_2 (Stumm and Morgan, 1981).
Liner soil/water partition coefficient	<i>In situ</i> tracer tests (Freeze and Cherry, 1979)	Batch experiment (Ash et al., 1973); column tests (van Genuchten and Wierenga, 1986).	Mills et al., 1985.
Soil oxygen content (aeration)	O_2 by membrane electrode O_2 diffusion rate by Pt microelectrode (Phene, 1986). O_2 by field GC (Smith, 1983).	Same as field.	Calculated from pE (Stumm and Morgan, 1981) or from O_2 and soil-gas diffusion rate.

(Continued)

TABLE 2. (CONTINUED)

Soil Characteristic*	Measurement Technique/Method (w/Reference)		
	Field	Laboratory	Calculation or Lookup Method
Soil temperature (as it affects volatilization)	Thermotery (Taylor and Jackson, 1986).	Same as field.	Brown and Associates (1980).
Clay mineralogy	Parent material analysis.	X-ray diffraction (Whittig and Allardice, 1986).	
Unsaturated hydraulic conductivity	Unsteady drainage-flux (or instantaneous profile) method and simplified unsteady drainage flux method (Green et al., 1986). The instantaneous profile method was initially developed as a laboratory method (Watson, 1966), however it was adapted to the field (Hillel et al., 1972). Constant-head borehole infiltration (Amoozegar and Warrick, 1986).	Not usually done; results very difficult to obtain.	A number of estimation methods exists, each with their own set of assumptions and requiremnts. Reviews have been presented by Mualem (1986), and van Gehuchten (in press).
Moisture content	Two types of techniques – indirect and direct. Direct methods, (i.e., gravimetric sampling), considered the most accurate, with no calibration required. However, methods are destructive to field systems. Methods involve collecting samples, weighing, drying and re-weighing to determine field moisture. Indirect methods rely on calibration (Klute, 1986).		
Soil biota	No standard method exists (see model or remedial technology for input or remedial evaluation procedures).	No standard method exists; can use agar plate count using MOSA method 99-3 p. 1462 (Klute, 1986).	

* Soil characteristics are discussed in general except where specific cases relate to different waste types (i.e., metals, hydrophobic organics or polar organics).

Significant advances have been made in understanding and describing the spatial variability of soil properties (Neilsen and Bouma, 1985). Geostatistical methods and techniques (Clark, 1982; Davis, 1986) are available for statistically characterizing soil properties important to contaminant migration. Information gained from a geostatistical analysis of data can be used for three major purposes:

- Determining the heterogeneity and complexity of the site;
- Guiding the data collection and interpretation effort and thus identifying areas where additional sampling may be needed (to reduce uncertainty by estimating error); and
- Providing data for a stochastic model of fluid flow and contaminant migration.

One of the geostatistical tools useful to help in the interpolation or mapping of a site is referred to as kriging (Davis, 1986). General kriging computer codes are presently available. Application of this type of tool, however, requires an adequate

sample size. As a rule of thumb, 50 or more data points are needed to construct the semivariogram required for use in kriging. The benefit of using kriging in site characterization is that it allows one to take point measurements and estimate soil characteristics at any point within the domain of interest, such as grid points, for a computer model. Geostatistical packages are available from the US EPA, Geo-EAS and GEOPACK (Englund and Sparks, 1988 and Yates and Yates, 1990).

The use of stochastic models in hydrogeology has increased significantly in recent years. Two stochastic approaches that have been widely used are the first order uncertainty method (Dettinger and Wilson, 1981) and Monte Carlo methods (Clifton et al., 1985; Sagar et al., 1986; Eslinger and Sagar, 1988). Andersson and Shapiro (1983) have compared these two approaches for the case of steady-state unsaturated flow. The Monte Carlo methods are more general and easier to implement than the first order uncertainty methods. However, the Monte Carlo method is more computationally intensive, particularly for multidimensional problems.

(Continued on page 10)

TABLE 3. SOIL CHARACTERISTICS REQUIRED FOR VADOSE ZONE MODELS

Properties and Parameters	Model Name [Reference(s)]									
	Help (A,B)	Sesoil (C,D)	Creams (E,F)	PRZM (G,H,I)	Vadofit (H,J)	Minteq (J)	Fowl TM (K)	Ritz (L)	Vip (M)	Chemflo (N)
Soil bulk density	●	●	●	●	●	●	●	●	●	●
Soil pH	○	●	●	○	○	●	●	○	○	○
Soil texture	●	●	●	●	●	●	●	●	●	●
Depth to ground water	●	●	●	●	●	●	●	●	●	●
Horizons (soil layering)	●	●	●	●	●	●	●	●	●	●
Saturated hydraulic conductivity	●	●	●	●	●	●	●	●	●	●
Water retention	●	●	●	●	●	●	●	○	○	●
Air permeability	○	●	○	●	●	○	○	●	●	○
Climate (precipitation)	●	●	●	●	●	○	●	●	●	●
Soil porosity	●	●	●	●	●	●	●	●	●	●
Soil organic content	○	●	●	●	●	●	●	●	●	●
Cation Exchange Capacity (CEC)	○	●	○	○	○	●	○	○	○	○
Degradation parameters	●	●	●	●	●	○	○	●	●	●
Soil grain size distribution	○	●	●	●	●	○	○	○	○	○
Soil redox potential	○	●	●	○	○	●	○	○	○	●
Soil/water partition coefficients	○	●	●	●	●	●	●	●	●	●
Soil oxygen content	○	●	○	○	○	●	○	○	●	○
Soil temperature	●	●	●	●	●	●	●	●	●	●
Soil mineralogy	○	●	○	○	○	●	○	○	○	○
Unsaturated hydraulic conductivity	●	●	●	●	●	●	●	○	○	●
Saturated soil moisture content	●	●	●	●	●	●	●	●	●	●
Microorganism population	○	●	○	○	○	○	○	○	●	○
Soil respiration	○	●	○	○	○	○	○	○	●	○
Evaporation	●	●	●	●	●	○	○	●	●	●
Air/water contaminant densities	●	●	●	●	●	○	●	●	●	●
Air/water contaminant viscosities	●	●	●	●	●	○	●	●	●	●

REFERENCES

- A. Schroeder, et al., 1984.
 B. Schroeder, et al., 1984a.
 C. Bonazountas and Wagner, 1984.
 D. Chen, Wollman, and Liu, 1987.
 E. Leonard and Ferrel, 1984.
 F. Devaux and Springer, 1988.
 G. Carsel et al., 1984.
 H. Dean et al., 1989.
 I. Dean et al., 1989a.
 J. Brown and Allison, 1987.
 K. Hosteller, Erickson, and Rai, 1988.
 L. Nofziger and Williams, 1988.
 M. Stevens et al., 1989.
 N. Nofziger et al., 1989.

● Required ○ Not required ● Used indirectly*

* Used in the estimation of other required characteristics or the interpretation of the models, but not directly entered as input to models.

Application of stochastic models to hazardous waste sites has two main advantages. First, this approach provides a rigorous way to assess the uncertainty associated with the spatial variability of soil properties. Second, the approach produces model predictions in terms of the likelihood of outcomes, i.e., probability of exceeding water quality standards. The use of models at hazardous waste sites leads to a thoughtful and objective treatment of compliance issues and concerns.

In order to obtain accurate results with models, quality data types must be used. The issue of quality and confidence in data can be partially addressed by obtaining as representative data as possible. Good quality assurance and quality control plans must be in place for not only the acquisition of samples, but also for the application of the models (van der Heijde, et al., 1989).

Specific soil characteristics vary both laterally and vertically in an undisturbed soil profile. Different soil characteristics have different variances. As an example, the sample size required to have 95 percent probability of detecting a change of 20 percent in the mean bulk density at a specific site was 6; however, for saturated hydraulic conductivity the sample size would need to be 502 (Jury, 1986). A good understanding of site soil characteristics can help the investigators understand these variations. This is especially true for most hazardous waste sites because the soils have often been disturbed, which may cause even greater variability.

An important aspect of site characterization data and models is that the modeling process is dynamic, i.e., as an increasing number of "simplifying" assumptions are needed, the complexity of the models must increase to adequately simulate the additional processes that must be included. Such simplifying assumptions might include an isotropic homogeneous medium or the presence of only one mobile phase (Weaver, et al., 1989). In order to decrease the number of assumptions required, there is usually a need to increase the number of site-specific soil characteristic data types in a model (see Table 2); thus providing greater confidence in the values produced. For complex sites, an iterative process of initial data collection and evaluation leading to more data collection and evaluation until an acceptable level of confidence in the evaluation can be reached can be used.

Table 3 identifies selected unsaturated zone models and their soil characteristic needs. For specific questions regarding use and application of the model, the reader should refer to the associated manuals. Some of these models are also reviewed by Donigan and Rao (1986) and van der Heijde et al. (1988).

SOIL CHARACTERISTICS DATA TYPES REQUIRED FOR REMEDIAL ALTERNATIVE SELECTION

Remedial Alternative Selection Procedure

The CERCLA process involves the identification, screening and analysis of remedial alternatives at uncontrolled hazardous waste sites (US EPA, 1988c). During screening and analysis, decision values for process-limiting characteristics for a given remedial alternative are compared to site-specific values of those characteristics. If site-specific values are outside the range required for effective use of a particular alternative, that alternative is less likely to be selected. Site soil conditions are critical process-limiting characteristics.

Process-Limiting Characteristics

Process-limiting characteristics are site- and waste-specific data types that are critical to the effectiveness and ability to implement remedial processes. Often, process-limiting characteristics are descriptors of rate-limiting steps in the overall remedial process. In some cases, limitations imposed by process-limiting characteristics can be overcome by adjustment of soil characteristics such as pH, soil moisture content, temperature and others. In other cases, the level of effort required to overcome these limitations will preclude use of a remedial process.

Decision values for process limiting characteristics are increasingly available in the literature, and may be calculated for processes where design equations are known. Process limiting characteristics are identified and decision values are given for several vadose zone remedial alternatives in Table 4. For waste/site characterization, process-limiting characteristics may be broadly grouped in four categories:

1. Mass transport characteristics
2. Soil reaction characteristics
3. Contaminant properties
4. Engineering characteristics

Thorough soil characterization is required to determine site-specific values for process-limiting characteristics. Most remedial alternatives will have process-limiting characteristics in more than one category.

Mass Transport Characteristics

Mass transport is the bulk flow, or advection of fluids through soil. Mass transport characteristics are used to calculate potential rates of movement of liquids or gases through soil and include:

Soil texture
Unsaturated hydraulic conductivity
Dispersivity
Moisture content vs. soil moisture tension
Bulk density
Porosity
Permeability
Infiltration rate, stratigraphy and others.

Mass transport processes are often process-limiting for both *in situ* and extract-and-treat vadose zone remedial alternatives (Table 4). *In situ* alternatives frequently use a gas or liquid mobile phase to move reactants or nutrients through contaminated soil. Alternatively, extract-and-treat processes such as soil vapor extraction (SVE) or soil flushing use a gas or liquid mobile phase to move contaminants to a surface treatment site. For either type of process to be effective, mass transport rates must be large enough to clean up a site within a reasonable time.

Soil Reaction Characteristics

Soil reaction characteristics describe contaminant-soil interactions. Soil reactions include bio- and physicochemical reactions that occur between the contaminants and the site soil. Rates of reactions such as biodegradation, hydrolysis, sorption/desorption, precipitation/dissolution, redox reactions, acid-base reactions, and others are process-limiting characteristics for

(Continued on page 12)

TABLE 4. SOIL CHARACTERIZATION CHARACTERISTICS REQUIRED FOR REMEDIAL TECHNOLOGY EVALUATION ,
(US EPA, 1988e,f; 1989a,b; 1990; Sims et al., 1986; Sims, 1990; Towers et al., 1989)

Technology	Process Limiting Characteristics	Site Data Required	Technology	Process Limiting Characteristics	Site Data Required
Pretreatment/ materials handling	Large particles interfere Clayey soils or hardpan difficult to handle Wet soils difficult to handle	Particle size distribution Soil moisture content	Thermal treatment (continued)	Particle size affects feeding and residuals pH <5 and >11 causes corrosion	Particle size distribution pH
Soil vapor extraction	Applicable only to volatile organics w/significant vapor pressure >1 mm Hg Low soil permeability inhibits air movement Soil hydraulic conductivity >1E-8 cm/sec required Depth to ground water >20 ft recommended High moisture content inhibits air movement High organic matter content inhibits contaminant removal	Contaminants present Soil permeability Hydraulic conductivity Depth to ground water Soil moisture content Organic matter content	Solidification/ stabilization	Not equally effective for all contaminants Fine particles < No. 200 mesh may interfere Oil and grease >10% may interfere	Contaminants present Particle size distribution Oil and grease
<i>In situ</i> enhanced bioremediation	Applicable only to specific organics Hydraulic conductivity >1E-4 cm/sec preferred to transport nutrients Stratification should be minimal Lower permeability layers difficult to remediate Temperature 15-45°C required Moisture content 40-80% of that at -1/3 bars tension preferred pH 4.5-3.5 required Presence of microbes required Minimum 10% air-filled porosity required for aeration	Contaminants present Hydraulic conductivity Soil stratigraphy Soil stratigraphy Soil temperature Soil moisture characteristic curves Soil pH Plate count Porosity and soil moisture content	Chemical extraction (slurry reactors)	Not equally effective for all contaminants Particle size <0.25 in. pH <10	Contaminants present Particle size distribution pH
Thermal treatment	Applicable only to organics Soil moisture content affects handling and heating requirements	Contaminants present Soil moisture content	Soil washing	Not equally effective for all contaminants Silt and clay difficult to remove from wash fluid	Contaminants present Particle size distribution
			Soil flushing	Not equally effective for all contaminants Required number of pore volumes	Contaminants present Infiltration rate and porosity
			Glycolate dechlorination	Not equally effective for all contaminants Moisture content <20% Low organic matter content required	Contaminants present Moisture content Organic carbon
			Chemical oxidation/ reduction (slurry reactor)	Not equally effective for all contaminants Oxidizable organics interfere pH <2 interferes	Contaminants present Organic carbon pH
			<i>In situ</i> vitrification	Maximum moisture content of 25% by weight Particle size <4 inches Requires soil hydraulic conductivity <1E-5 cm/sec	Moisture content Particle size distribution Hydraulic conductivity

many remedial alternatives (Table 4). Soil reaction characteristics include:

- K_d , specific to the site soils and contaminants
- Cation exchange capacity (CEC)
- Eh
- pH
- Soil biota
- Soil nutrient content
- Contaminant abiotic/biological degradation rates
- Soil mineralogy
- Contaminant properties, described below, and others.

Soil reaction characteristics determine the effectiveness of many remedial alternatives. For example, the ability of a soil to attenuate metals (typically described by K_d) may determine the effectiveness of an alternative that relies on capping and natural attenuation to immobilize contaminants.

Soil Contaminant Properties

Contaminant properties are critical to contaminant-soil interactions, contaminant mobility, and to the ability of treatment technologies to remove, destroy or immobilize contaminants. Important contaminant properties include:

- Water solubility
- Dielectric constant
- Diffusion coefficient
- K_{oc}
- K_d
- K_{ow}
- Molecular weight
- Vapor pressure
- Density
- Aqueous solution chemistry, and others.

Soil contaminant properties will determine the effectiveness of many treatment techniques. For example, the aqueous solution chemistry of metal contaminants often dictates the potential effectiveness of stabilization/solidification alternatives.

Soil Engineering Characteristics and Properties

Engineering characteristics and properties of the soil relate both to implementability and effectiveness of the remedial action. Examples include the ability of the treatment method to remove, destroy or immobilize contaminants; the costs and difficulties in installing slurry walls and other containment options at depths greater than 60 feet; the ability of the site to withstand vehicle traffic (trafficability); costs and difficulties in deep excavation of contaminated soil; the ability of soil to be worked for implementation of *in situ* treatment technologies (tilth); and others. Knowledge of site-specific engineering characteristics and properties is therefore required for analysis of effectiveness and implementability of remedial alternatives. Engineering characteristics and properties include, but are not limited to:

- Trafficability
- Erodability
- Tilth
- Depth to groundwater
- Thickness of saturated zone
- Depth and total volume of contaminated soil
- Bearing capacity, and others.

SUMMARY AND CONCLUSIONS

The goal of the CERCLA RI/FS process is to reach a ROD in a timely manner. Soil characterization is critical to this goal. Soil characterization provides data for RI/FS tasks including determination of the nature and extent of contamination, risk assessment, and selection of remedial techniques.

This paper is intended to inform investigators of the data types required for RI/FS tasks, so that data may be collected as quickly, efficiently, and cost effectively as possible. This knowledge should improve the consistency of site evaluations, improve the ability of OSCs and RPMs to communicate data needs to site contractors, and aid in the overall goal of reaching a ROD in a timely manner.

REFERENCES

American Society for Testing and Materials, 1985. Density of soil and soil aggregate in place by nuclear methods (shallow depth). ASTM, Philadelphia, PA.

ASTM, 1987. American Society for Testing and Materials, Standard practice for oxidation-reduction potential of water. ASTM D1498-76. ASTM, Philadelphia, PA.

ASTM, 1987. American Society for Testing and Materials. Standard Test Method for Determining a Sorption Constant (K_d) for an Organic Chemical in Soil and Sediments E1195-87. Annual Book ASTM Standards, Vol. 11.02 p. 731.

Amoozegar, A. and A. W. Warrick, 1986. Hydraulic Conductivity of Saturated Soils. In Klute, A. ed. *Methods of Soil Analysis Part 1: Physical and Mineralogical Methods*, 2nd edition. Monograph 9 (Part 1), American Society of Agronomy, Inc./Soil Science Society of America, Inc. Publisher, Madison, WI.

Andersson, J. and A. M. Shapiro, 1983. "Stochastic Analysis of One-Dimensional Steady-State Unsaturated Flow: A Comparison of Monte Carlo and Perturbation Methods," Water Resources Research, Vol. 19, No. 1, pp. 121-133.

Ash, S. G., R. Brown, and D. H. Everett, 1973. A high-precision apparatus for the determination of adsorption at the interface between a solid and a solution. *J. Chem. Thermodynamics* 5: 239-246.

Barth, D. S., B. J. Mason, T. H. Starks, and K. W. Brown. 1989. *Soil Sampling Quality Assurance User's Guide*. EPA 600/8-89/046, U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Las Vegas, NV.

Blake, G. R., 1965. Bulk Density. In Black, C. A. ed. *Methods of Soil Analysis*. Part 1. Monograph 9, Part 1, Am. Soc. of Agronomy, Madison, WI.

Blake, G. R. and K. H. Hartge, 1986. Bulk density. In Klute, A. ed. *Methods of Soil Analysis Part 1: Physical and Mineralogical Methods*, 2nd edition. Monograph 9 (Part 1), American Society of Agronomy, Inc./Soil Science Society of America, Inc. Publisher, Madison, WI.

- Bonazountas, M. and J. M. Wagner, 1984. *SESOIL: A Seasonal Soil Compartment Model*. Contract No. 68-01-6271, Draft Report from Arthur D. Little, Inc. U.S. Environmental Protection Agency, Office of Toxic Substances, Washington, DC.
- Brady, Nyle C., 1974. *The Nature and Properties of Soils*, MacMillan Publishing Co., Inc., NY.
- Brooks, R. H. and A. T. Corey, 1964. "Hydraulic properties of porous media", Hydrology Paper No. 3, 27 pp. Colorado State University, Fort Collins, CO.
- Brown, D. S. and J. D. Allison, 1987. *MINTEQA1 Equilibrium Metal Speciation Model: A User's Manual*. U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, GA.
- Brown, K. W. and Associates, 1980. Hazardous waste land treatment. Draft edition. SW-874. U.S. Environmental Protection Agency, Cincinnati, OH.
- K. W. Brown, R. P. Breckenridge, and R. C. Rope, 1990. *U.S. Fish and Wildlife Service Contaminant Monitoring Operations Manual: Appendix J, Soil Sampling Reference Field Methods*, EGG-EST-9222, EG&G Idaho, Inc, Idaho Falls, ID.
- Bruce, R. R. and R. J. Luxmoore, 1986. Water Retention: Field Methods. In Klute, A., ed. *Methods of Soil Analysis Part 1: Physical and Mineralogical Methods*, 2nd edition. Monograph 9 (Part 1), American Society of Agronomy, Inc./Soil Science Society of America, Inc. Publisher, Madison, WI.
- Campbell, G. S., 1985. *Soil Physics with Basic*, Elsevier, New York, NY.
- Carsel, R. F., C. N. Smith, L. A. Mulkey, J. D. Dean, and P. Jowise, 1984. *Users Manual for the Pesticide Root zone Model (PRZM): Release 1*. U. S. Environmental Protection Agency, Environmental Research Laboratory, Athens, GA.
- Chen, J., S. Wollman, and J. Liu, 1987. *User's Guide to SESOIL Execution in GEMS*. GSC-TR8747. Prepared by General Sciences Corporation. U.S. Environmental Protection Agency, Office of Pesticides and Toxic Substances. Washington, DC.
- Clark, I., 1982. *Practical Geostatistics*, Applied Science Publishers Ltd, London, England.
- Clifton, P. M., R. G. Baca, R. C. Arnett, 1985. "Stochastic Analysis of Groundwater Traveltimes for Long-Term Repository Performance Assessment," in the Proceedings of the Materials Research Society Symposium-Scientific Basis for Nuclear Waste Management, Boston, MA.
- Corey, A. T., 1986. Air Permeability. In Klute, A., ed. *Methods of Soil Analysis Part 1: Physical and Mineralogical Methods*, 2nd edition. Monograph 9 (Part 1), American Society of Agronomy, Inc./Soil Science Society of America, Inc. Publisher, Madison, WI.
- Cowherd, C., Mulseki, G. E., Englehart, P. J., and Gillette, D. A., 1985. PB85-192219, *Rapid assessment of exposure to particulate emissions from surface contamination sites*. Midwest Research Institute, Kansas City, MO.
- Danielson, R. E. and P. L. Sutherland, 1986. Porosity. In Klute, A. ed. *Methods of Soil Analysis Part 1: Physical and Mineralogical Methods*, 2nd edition. Monograph 9 (Part 1), American Society of Agronomy, Inc./Soil Science Society of America, Inc. Publisher, Madison, WI.
- Davis, J. C., 1986. *Statistics and Data Analysis in Geology*, Second Edition, John Wiley and Sons, New York, NY.
- Dean, J. D., P. S. Huyakorn, A. S. Donigian, Jr., K. A. Voos, R. W. Schanz, and R. F. Carsel, 1989. *Risk of Unsaturated/Saturated Transport and Transformation of Chemical Concentrations (RUSTIC): Volume I. Theory and Code Verification*. EPA/600/3-89/048a. U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, GA.
- Dettinger, M. D. and J. L. Wilson, 1981. "First Order Analysis of Uncertainty in Numerical Models of Groundwater Flow, Part 1, Mathematical Development," Water Resources Research, Vol. 16, No. 1, pp. 149-161.
- Devaurs, M. and E. Springer, 1988. "Representing Soil Moisture in Experimental Trench Cover Designs for Waste Burial with the CREAMS Model". *Hazardous Waste and Hazardous Material*. Vol. 5, No. 4, pp. 295-312.
- Donigian, A. S., Jr. and P. S. C. Rao, 1986. Overview of Terrestrial Processes and Modeling. In Hern, S. C. and S. M. Melancon. 1986. *Vadose Zone Modeling of Organic Pollutants*, Lewis Publishers, Inc., Chelsea, MI.
- Dragun, J. 1988. "The Fate of Hazardous Materials in Soil (What Every Geologist and Hydrogeologist Should Know), Part 1. HMC 1(2): 30-78.
- Dragun, J. 1988a. "The Fate of Hazardous Materials in Soil (What Every Geologist and Hydrogeologist Should Know), Part 2. HMC 1(3): 40-65.
- Dragun, J. 1988b. "The Fate of Hazardous Materials in Soil (What Every Geologist and Hydrogeologist Should Know), Part 3. HMC 1(5): 24-43.
- Englund, E. and A. Sparks, 1988. *GEO-EAS (Geostatistical Environmental Assessment Software) User's Guide*. EPA/600/4-88/033.
- Eslinger, P. W. and B. Sagar, 1988. *EPASTAT: A Computer Model for Estimating Releases at the Accessible Environment Boundary of a High-Level Nuclear Waste Repository - Mathematical Model and Numerical Model*, SD-BWI-TA-022, Rockwell Hanford Operations, Richland, WA.
- Finkelstein, F. L., D. A. Mazzarella, T. A. Lockhart, W. J. King, and J. H. White, 1983. *Quality Assurance Handbook for Air Pollution Measurement Systems. IV: Meteorological Measurements*, EPA-600/4-82-060, Washington, DC.
- Freeze, R. A. and J. A. Cherry, 1979. *Groundwater*. Prentice-Hall. Englewood Cliffs, NJ.

- Gardner, W. H. 1986. Water content. In Klute, A., ed. *Methods of Soil Analysis Part 1: Physical and Mineralogical Methods*, 2nd edition. Monograph 9 (Part 1), American Society of Agronomy, Inc./Soil Science Society of America, Inc. Publisher, Madison, WI.
- Gee, G. W. and J. W. Bauder. Particle-size Analysis. In Klute, A., ed. *Methods of Soil Analysis Part 1: Physical and Mineralogical Methods*, 2nd edition. Monograph 9 (Part 1), American Society of Agronomy, Inc./Soil Science Society of America, Inc. Publisher, Madison, WI.
- Green, R. E., L. R. Ahuja, and S. K. Chong. 1986. Hydraulic Conductivity, Diffusivity, and Sorptivity of Unsaturated Soils: Field Methods. In Klute, A., ed. *Methods of Soil Analysis Part 1: Physical and Mineralogical Methods*, 2nd edition. Monograph 9 (Part 1), American Society of Agronomy, Inc./Soil Science Society of America, Inc. Publisher, Madison, WI.
- Hillel, D., 1980. *Application of Soil Physics*, Academic Press, Inc., New York, NY.
- Hillel, D., 1980a. *Fundamentals of Soil Physics*, Academic Press, Inc., New York, NY.
- Hillel, D., V. D. Krentos, Y. Stylianou, 1972. "Procedure and Test of an Internal Drainage Method for Measuring Soil Hydraulic Characteristics *in situ*", *Soil Science* 114:395-400.
- Hostetler, C. J., R. L. Erikson, and D. Ral, 1988. *The Fossil Fuel Combustion Waste Leaching (FOWL) Code: Version 1. User's Manual*. EPRI EA-57420CCM. Electric Power Research Institute. Palo Alto, CA.
- Israelsen, C. E., Clyde, C. G., Fletcher, J. E., Israelsen, E. K., Haws, F. W., Packer, P. E., and Farmer, E. E., Erosion Control During Highway Construction. Manual on Principles and Practices. Transportation Research Board, National Research Council, Washington, DC 1980.
- Jenkins, R. A., W. H. Griest, R. L. Moody, M. V. Buchanan, M. P. Maskarinec, F. F. Dyer, C. -h. Ho, 1988. *Technology Assessment of Field Portable Instrumentation for Use at Rocky Mountain Arsenal*, ORNL/TM-10542, Oak Ridge National Laboratory, Oak Ridge, TN.
- Jury, W. A., 1986. Spatial Variability of Soil Properties. In Hern, S. C. and S. M. Melancon. *Vadose Zone Modeling of Organic Pollutants*. Lewis Publishers, Inc., Chelsea, MI.
- Kite, J. W., 1979. *Guideline for the Design, Installation, and Operation of a Meteorological System*, Radian Corporation, Austin, TX.
- Klute, A., 1986. Water Retention: Laboratory Methods. In Klute, A. ed. *Methods of Soil Analysis Part 1: Physical and Mineralogical Methods*, 2nd edition. Monograph 9 (Part 1), American Society of Agronomy, Inc./Soil Science Society of America, Inc. Publisher, Madison, WI.
- Leonard, R. A., and V. A. Ferreira, 1984. "CREAMS2 - The Nutrient and Pesticide Models", Proceedings of the Natural Resources Modeling Symposium, U.S. Department of Agriculture.
- Mills, W. B., D. B. Procella, M. J. Unga, S. A. Gherini, K. V. Summers, L. Mok, G. L. Rupp, G. L. Bowie, and D. A. Haith, 1985. EPA/600/6-85-002a, *Water quality assessment: A screening procedure for toxic and conventional pollutants in surface and ground water. Part 1*. Tetra Tech Inc., Lafayette, CA.
- Mills, W. B., Dean, J. D., Porcella, D. B., et al., 1982. Water quality assessment: a screening procedure for toxic and conventional pollutants: parts 1, 2, and 3, Athens, GA: U.S. Environmental Protection Agency. Environmental Research Laboratory. Office of Research and Development. EPA-600/6-82/004 a.b.c.
- Mualem, Y. 1986. Hydraulic Conductivity of Unsaturated Soils: Prediction and Formulas. In Klute, A. ed. *Methods of Soil Analysis Part 1: Physical and Mineralogical Methods*, 2nd edition. Monograph 9 (Part 1), American Society of Agronomy, Inc./Soil Science Society of America, Inc. Publisher, Madison, WI.
- Neilson, D. R. and J. Bouma, eds, 1985. *Soil Spatial Variability*, Center for Agricultural Publishing and Documentation, Wageningen, the Netherlands.
- Nofziger, D. L., K. Rajender, S. K. Nayudu, and P. Y. Su, 1989. *CHEMFLOW: One-Dimensional Water and Chemical Movement in Unsaturated Soils*. EPA/600/8-89/076. U. S. Environmental Protection Agency. Robert S. Kerr Environmental Research Laboratory, Ada, OK.
- Nofziger, D. L. and J. R. Williams, 1988. *Interactive Simulation of the Fate of Hazardous Chemicals During Land Treatment of Oily Wastes: RITZ User's Guide*. EPA/600/8-88/001. U. S. Environmental Protection Agency. Robert S. Kerr Environmental Research Laboratory, Ada, OK.
- Phene, C. J., 1986. Oxygen electrode measurement. In Klute, A. ed. *Methods of Soil Analysis Part 1: Physical and Mineralogical Methods*, 2nd edition. Monograph 9 (Part 1), American Society of Agronomy, Inc./Soil Science Society of America, Inc. Publisher, Madison, WI.
- Powell, R. M., Bledsoe, B. E., Johnson, R. L., and G. P. Curtis, "Interlaboratory Methods Comparison for the Total Organic Carbon Analysis of Aquifer Materials", *Environmental Science and Technology*, Vol. 23, pp. 1246-1249.
- Powell, R. M., 1990. "Total Organic Carbon Determinations in Natural and Contaminated Aquifer Materials, Relevance and Measurement", Proceedings of the Fourth National Outdoor Action Conference on Aquifer Restoration, Ground water Monitoring and Geophysical Methods (National Water Well Association), May 14-17, 1990, Las Vegas, NV.
- Reynolds, W. D. and D. E. Elrick, 1985. *In situ* Measurement of Field-Saturated Hydraulic Conductivity, Sorptivity and the α -Parameter using the Guelph Permeameter. *Soil Science* 140(4):292-302.
- Reynolds, W. D. and D. E. Elrick, 1986. A Method for Simultaneous *in situ* Measurement in the Vadose zone of Field-Saturated Hydraulic Conductivity, Sorptivity, and the Conductivity-Pressure Head Relationship. *Ground Water Monitoring Review* 6(1):84-95.

- Rhoades, J.D., 1982. Cation Exchange Capacity. In Page, A. L., R. H. Miller, and D. R. Keeney, eds; *Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties*, 2nd edition, American Society of Agronomy Monograph 9 (Part 2), Madison, WI.
- Roco, M. C., J. Khadilkar, and J. Zhang, 1989. "Probabilistic Approach for Transport of Contaminants Through Porous Media," *International Journal for Numerical Methods in Fluids*, Vol. 9, pp. 1431-1451.
- Sagar, B., P. W. Eslinger, and R. G. Baca, 1986. "Probabilistic Modeling of Radionuclide Release at the Waste Package Subsystems Boundary of a Repository in Basalt," *Nuclear Technology*, Vol. 75, pp. 338-349.
- Schroeder, P.R., J. M. Morgan, T. M. Walski, and A. C. Gibson, 1984. *Hydrologic Evaluation of Landfill Performance (HELP) Model: Volume I. User's Guide for Version 1*. EPA/530-SW-84-009, U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, Cincinnati, OH.
- Schroeder, P. R., A. C. Gibson, and M. D. Smolen, 1984. *Hydrologic Evaluation of Landfill Performance (HELP) Model: Volume II. Documentation for Version 1*. EPA/530-SW-84-010. U. S. Environmental Protection Agency, Municipal Environmental Research Laboratory, Cincinnati, OH.
- Sims, R. C. 1990. Soil Remediation Techniques at Uncontrolled Hazardous Waste Sites: A Critical Review. *Journal of the Air and Waste Management Association*, Vol. 40, No. 5, pp. 704-732.
- Sims, J. L., R. C. Sims, and J. E. Matthews, 1989. EPA/600/9-89/073, *Bioremediation of Contaminated Surface Soils*, US EPA Environmental Research Laboratory, Ada, OK.
- Sims, R. C., D. Sorenson, J. Sims, J. McLean, R. Mahmood, R. Dupont, J. Jurinak, and K. Wagner, 1986. *Contaminated Surface Soils In-Place Treatment Techniques*. Pollution Technology Review No. 132. Noyes Publications, Park Ridge, NJ.
- Smith, K. A. 1983. Gas chromatographic analysis of the soil atmosphere. In K. A. Smith (ed.) *Soil Analysis*. Instrumental techniques and related procedures. Marcel Dekker Inc. New York, NY.
- Soil Conservation Service (SCS), USDA, 1951. Soil survey manual. U.S. Department of Agriculture Handbook 18, p. 228, U.S. Government Printing Office, Washington, DC.
- Soil Survey Staff, 1990. *Keys to Soil Taxonomy*. Soil Management Support Services. SMSS Technical Monograph #19, 4th edition. Virginia Polytechnic Institute, International Soils, Department of Crop and Soil Environmental Science, Blacksburg, VA.
- Stevens, D. K., W. J. Grenney, Z. Yan, and R. C. Sims, 1989. *Sensitive Parameter Evaluation for a Vadose Zone Fate and Transport Model*. EPA/600.2-89/039. U. S. Environmental Protection Agency. Robert S. Kerr Environmental Research Laboratory, Ada, OK.
- Stumm, W. and J. J. Morgan, 1981. *Aquatic Chemistry*. 2nd edition. Wiley-Interscience, NY.
- Taylor, S. A. and G. L. Ashcroft, 1972. *Physical Edaphology. The Physics of Irrigated and Nonirrigated Soils*, W. H. Freeman and Company, San Francisco, CA.
- Taylor, S. A. and R. D. Jackson, 1986. Temperature. In Klute, A. ed. *Methods of Soil Analysis Part 1: Physical and Mineralogical Methods*, 2nd edition. Monograph 9 (Part 1), American Society of Agronomy, Inc./Soil Science Society of America, Inc. Publisher, Madison, WI.
- Towers, D. S., M. J. Dent, and D. G. Van Arnam, 1988. *Evaluation of In Situ Technologies for VHOs Contaminated Soil*. In: *Proceedings of the 6th National Conference on Hazardous Wastes and Hazardous Materials*. Sponsored by the Hazardous Materials Control Research Institute.
- US EPA, 1985a. *Practical Guide for Ground-water Sampling*, EPA 600/2-85-104, Environmental Research Laboratory, Ada, OK.
- US EPA, 1985b. *Compilation of Air Pollutant Emission Factors. Volume 1. Stationary Point and Area Sources*. Fourth Edition. Office of Research and Development. Research Triangle Park, NC.
- US EPA, 1987a. *Data Quality Objectives for Remedial Response Activities*, EPA/540/G-87/003 (NTIS PB88-131370), Office of Emergency and Remedial Response and Office of Waste Programs Enforcement, Washington, D.C. 20460.
- US EPA, 1987b. *Compendium of Superfund Field Operating Methods*, EPA-540 P-87-001. OSWER Directive 9355.0-14. Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, DC.
- USEPA, 1988a. *Field Screening Methods for Hazardous Waste Site Investigations*, Proceedings from the First International Symposium, October 11-13, 1988.
- US EPA, 1988b. *Field Screening Methods Catalog. User's Guide*. EPA/540/2-88/005. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC.
- US EPA, 1988c. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA: Interim Final*. EPA/540/G-89/004. Office of Emergency and Remedial Response, U. S. Environmental Protection Agency, Washington, DC.
- US EPA. 1988d. *Superfund Exposure Assessment Manual*. EPA-540-1-88-001. OSWER Directive 9285.5-1. Office of Remedial Response, U.S. Environmental Protection Agency, Washington, DC.
- US EPA, 1988e. *Technology Screening Guide for Treatment of CERCLA Soils and Sludges*. EPA/540/2-88/004; NTIS# PB89-132674. U.S. Environmental Protection Agency, Washington, DC.

US EPA, 1988f. *Cleanup of Releases from Petroleum USTs: Selected Technologies*. EPA/530/UST-88/001. U.S. Environmental Protection Agency, Office of Underground Storage Tanks, Washington, DC 20640.

US EPA, 1989a. *Seminar on Site Characterization for Subsurface Remediations*. CERL-89-224. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC 20460.

US EPA, 1989b. *Bioremediation of Hazardous Waste Sites Workshop: Speaker Slide Copies and Supporting Information*. CERL-89-11. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC 20460.

US EPA, 1990. *Handbook on In Situ Treatment of Hazardous Waste-Contaminated Soils*. EPA/540/2-90/002. U.S. Environmental Protection Agency Risk Reduction Engineering Laboratory, Cincinnati, OH.

van der Heijde, P. K. M., A. I. El-Kadi, and S. A. Williams, 1988. *Ground Water Modeling: An Overview and Status Report*. EPA/600/2-89/028.

van der Heijde, P.K.M., W. I. M. Elderhorst, R. A. Miller, and M. J. Trehan, 1989. *The Establishment of a Groundwater Research Data Center for Validation of Subsurface Flow and Transport Models*. EPA/600/2-89/040, July 1989.

van Genuchten (in press). Proceedings of the International Workshop on Indirect Methods for Estimating the Hydraulic Properties of Unsaturated Soils, Riverside, CA, October 11-13, 1989. Univ. of CA-Riverside and U.S. Department of Agriculture.

van Genuchten, M. Th. 1980. A Closed-form equation for predicting the hydraulic conductivity of unsaturated soils. *Soil Sci. Soc. Am. J.* 44:892-898.

van Genuchten, M. and P. J. Wierenga, 1986. Solute dispersion coefficients and retardation factors. In Klute, A. ed. *Methods of Soil Analysis Part 1: Physical and Mineralogical Methods*, 2nd edition. Monograph 9 (Part 1), American Society of Agronomy, Inc./Soil Science Society of America, Inc. Publisher, Madison, WI.

Watson, K. K. 1986. An Instantaneous Profile Method for Determining the Hydraulic Conductivity of Unsaturated Porous Media. *Water Resources Research* 2:709-715.

Weaver, J., C. G. Enfield, S. Yates, D. Kreamer, and D. White, 1989. *Predicting Subsurface Contaminant Transport and Transformation: Considerations for Model Selection and Field Validation*. EPA/600/2-89/045, August 1989.

Whittig, L. D. and W. R. Allardice, 1986. X-Ray Diffraction Techniques. In A. Klute, ed. *Methods of Soil Analysis Part 1: Physical and Mineralogical Methods*, 2nd edition. Monograph 9 (Part 1), American Society of Agronomy, Inc./Soil Science Society of America, Inc. Publisher, Madison, WI.

Williams, J. R. 1975. Sediment-yield prediction with the universal equation using runoff energy factor. In Present and prospective technology for predicting sediment yields and sources. ARS-S-40. U.S. Department of Agriculture.

Yates, S. R. and M. V. Yates, 1990. *Geostatistics for Waste Management: A User's Guide for the GEOPACK (Version 1.0) Geostatistical Software System*. EPA/600/8-90/004, January 1990.

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati, OH 45268

BULK RATE
POSTAGE & FEES PAID
EPA PERMIT NO. G-35

Official Business
Penalty for Private Use \$300

EPA/540/4-91/003

CORRESPONDENCE DISTRIBUTION COVERSHEET

Author

Addressee

Correspondence No.

PS Innis, EPA

SH Wisness, RL

Incoming: 9102819

Subject: REVIEW OF THE DRAFT REMEDIAL INVESTIGATION/FEASIBILITY STUDY WORK PLAN
FOR THE 100-FR-1 OPERABLE UNIT, HANFORD SITE

INTERNAL DISTRIBUTION

Approval	Date	Name	Location	w/att
		Correspondence Control	A3-01	X
		President's Office	B3-01	
		M. R. Adams	H4-55	
		R. J. Bliss (Level I)	B3-04	
		L. C. Brown	H4-51	
		W. T. Dixon	B2-35	
		C. J. Geier	B2-19	
		V. W. Hall	L4-88	
		H. D. Harmon	R2-52	
		K. L. Hoewing	B3-06	
		J. O. Honeyman	A4-25	
		K. R. Jordan	B3-51	
		M. K. Korenko	B3-08	
		R. E. Lerch (Assignee)	B2-35	X
		H. E. McGuire	B2-35	
		L. L. Powers	B2-35	X
		T. B. Veneziano	B2-35	
		T. M. Wintczak	L4-92	X
		R. D. Wojtasek	L4-92	X
		- EDMC	H4-22	X

